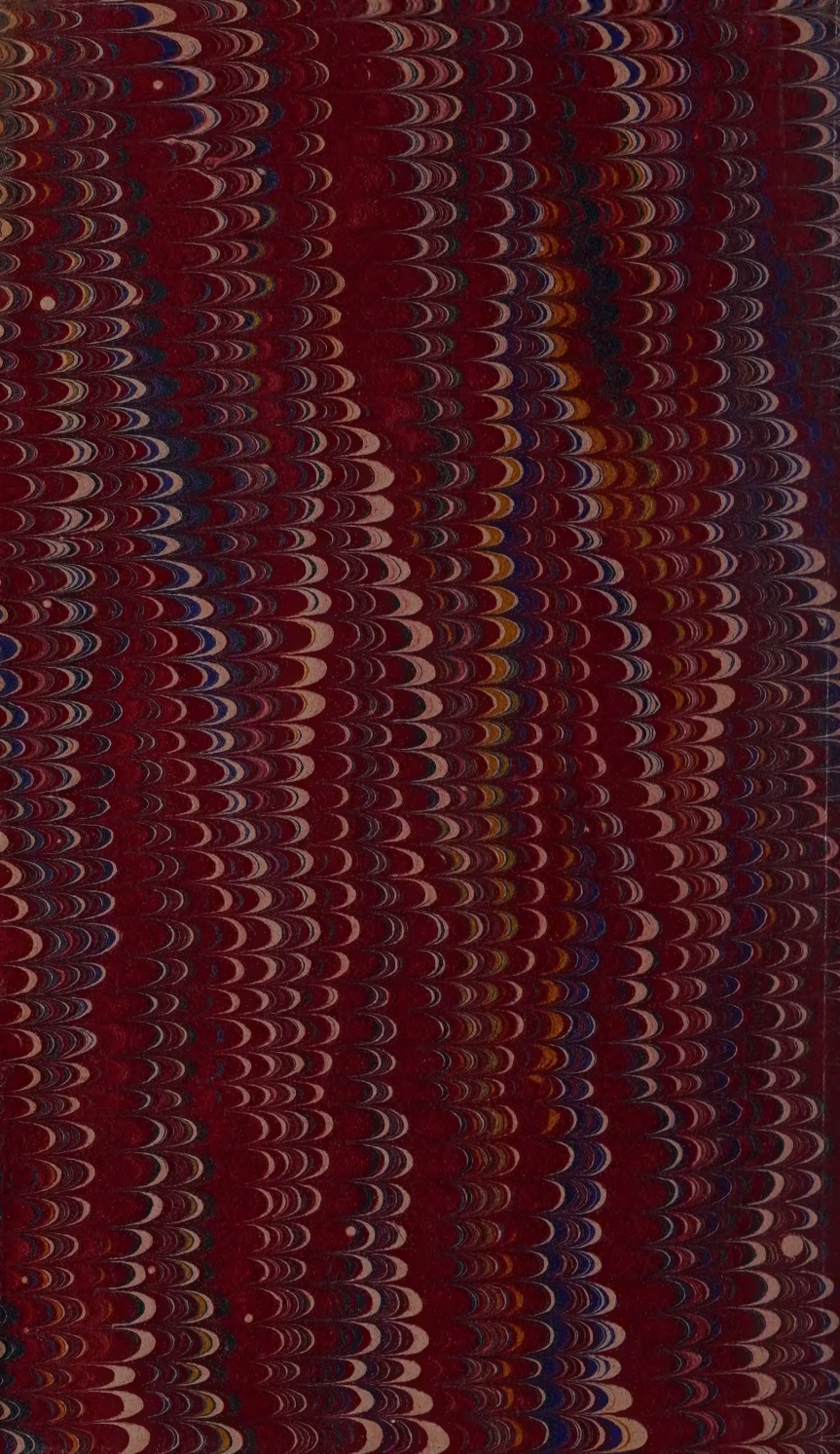
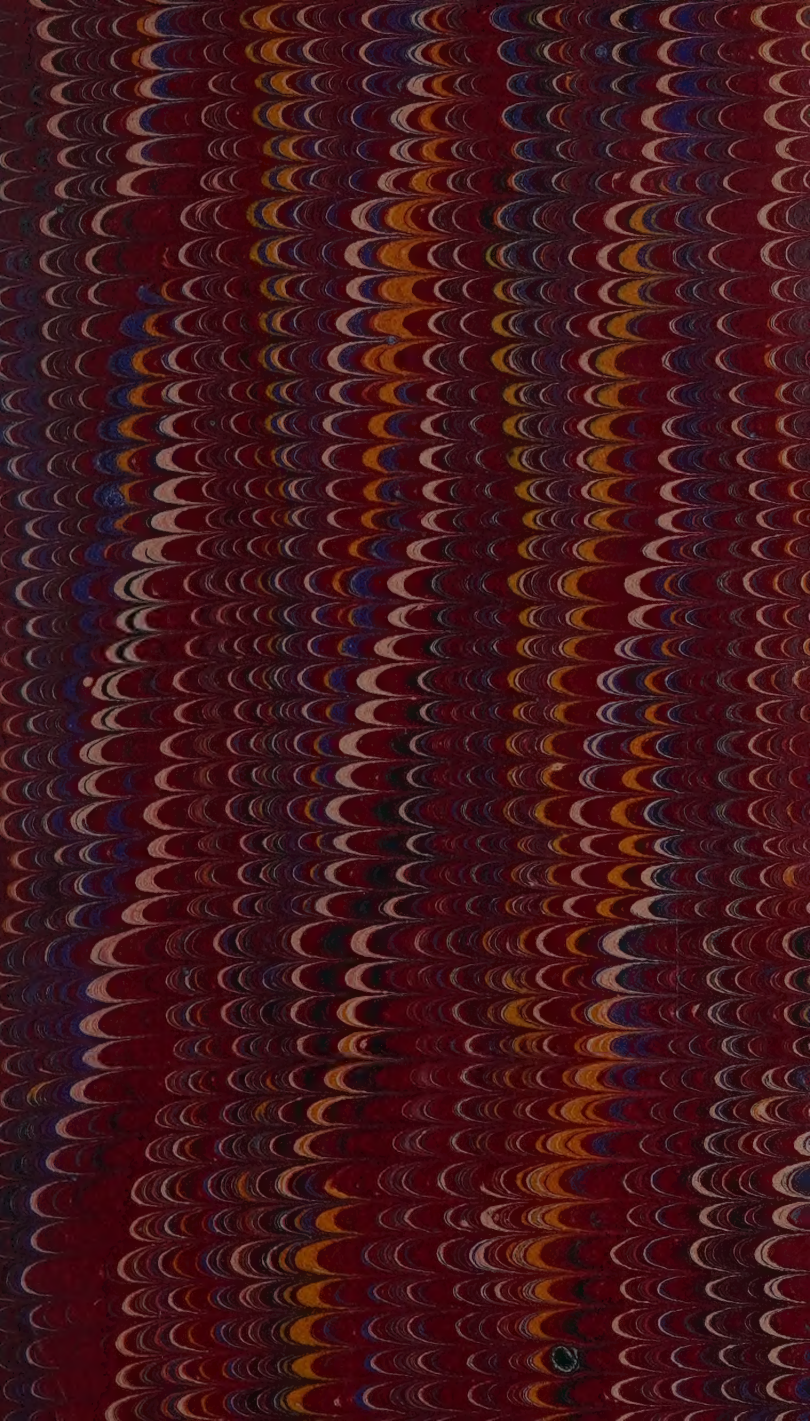






















THE ELEMENTS  
OF  
CIVIL ENGINEERING

PREPARED FOR STUDENTS OF  
THE INTERNATIONAL CORRESPONDENCE SCHOOLS  
SCRANTON, PA.

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**Volume XII**

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ANSWERS TO QUESTIONS  
IN VOLS. III-VIII

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**First Edition**

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A KEY  
TO ALL THE  
QUESTIONS AND EXAMPLES  
INCLUDED IN  
VOLS. III TO VIII,  
EXCEPT THE  
EXAMPLES FOR PRACTICE.

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It will be noticed that the Key is divided into sections which correspond to the sections containing the questions and examples at the end of Vols. III to VIII. The answers and solutions are so numbered as to be similar to the numbers before the questions to which they refer.



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# SURVEYING.

(QUESTIONS 614-705.)

(614) Let  $x$  = number of degrees in angle  $C$ ; then,  $2x$  = angle  $A$  and  $3x$  = angle  $B$ . The sum of  $A$ ,  $B$ , and  $C$  is  $x + 2x + 3x = 6x = 180^\circ$ , or  $x = 30^\circ = C$ ;  $2x = 60^\circ = A$ , and  $3x = 90^\circ = B$ . Ans.

(615) Let  $x$  = number of degrees in one of the equal angles; then,  $2x$  = their sum, and  $2x \times 2 = 4x$  = the greater angle.  $2x + 4x = 6x$  = sum of the three angles =  $180^\circ$ ; hence,  $x = 30^\circ$ , and the greater angle =  $30^\circ \times 4 = 120^\circ$ . Ans.

(616)  $AB$  in Fig. 55 is the given diagonal 3.5 in.  $3.5^2 = 12.25 \div 2 = 6.125$  in.  $\sqrt{6.125} = 2.475$  in. = side of the required square. From  $A$  and  $B$  as centers with radii equal to 2.475 in., describe arcs intersecting at  $C$  and  $D$ . Connect the extremities  $A$  and  $B$  with the points  $C$  and  $D$  by straight lines. The figure  $ACBD$  is the required square.

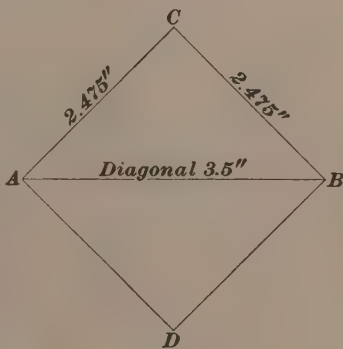


FIG. 55.

(617) Let  $AB$ , Fig. 56, be the given shorter side of the rectangle, 1.5 in. in length. At  $A$  erect an indefinite perpendicular  $AC$  to the line  $AB$ . Then, from  $B$  as a center with a radius of 3 in. describe an arc intersecting the perpendicular  $AC$  in the point  $D$ . This will give us two

adjacent sides of the required rectangle. At  $B$  erect an indefinite perpendicular  $BE$  to  $AB$ , and at  $D$  erect an indefinite perpendicular  $DF$  to  $AD$ . These perpendiculars

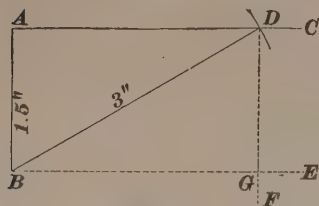


FIG. 56.

will intersect at  $G$ , and the resulting figure  $ABGD$  will be the required rectangle. Its area is the product of the length  $AD$  by the width  $AB$ .  $AD^2 = BD^2 - AB^2$ .  $BD^2 = 9$  in.;  $AB^2 = 2.25$  in.; hence,  $AD^2 = 9$  in.  $- 2.25$  in.  $= 6.75$  in.  $\sqrt{6.75} = 2.598$  in.  $=$  side

$AD$ .  $2.598$  in.  $\times 1.5 = 3.897$  sq. in., the area of the required rectangle.

(618) (See Fig. 57.) With the two given points as centers, and a radius equal to  $3.5 \div 2 = 1.75'' = 1\frac{3}{4}''$ , describe short arcs intersecting each other. With the same radius and with the point of intersection as a center, describe a circle; it will pass through the two given points.

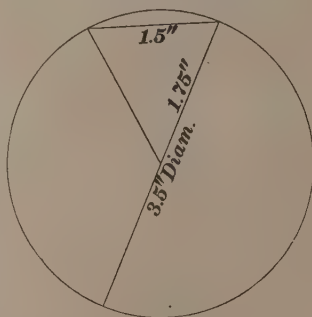


FIG. 57.

(619)  $AB$  in Fig. 58 is the given line,  $A$  the given point,  $AC$  and  $CB = AB$ .

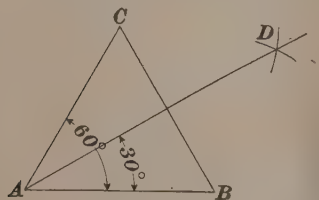


FIG. 58.

The angles  $A$ ,  $B$ , and  $C$  are each equal to  $60^\circ$ . From  $B$  and  $C$  as centers with equal radii, describe arcs intersecting at  $D$ . The line  $AD$  bisects the angle  $A$ ; hence, angle  $BAD = 30^\circ$ .

(620) Let  $AB$  in Fig. 59 be one of the given lines, whose length is 2 in., and let  $AC$ , the other line, meet  $AB$  at  $A$ , forming an angle of  $30^\circ$ . From  $A$  and  $B$  as centers,



with radii equal to  $AB$ , describe arcs intersecting at  $D$ . Join  $AD$  and  $BD$ . The triangle  $ABD$  is equilateral; hence, each of its angles, as  $A$ , contains  $60^\circ$ . From  $D$  as a

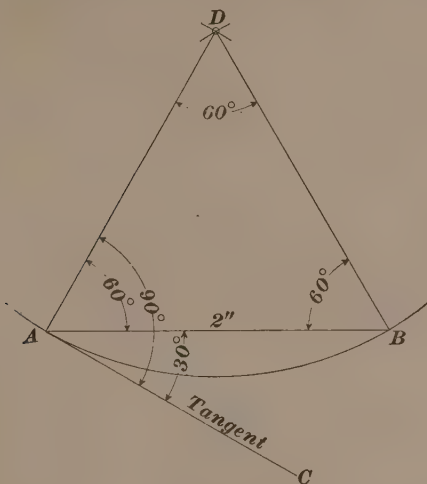


FIG. 59.

center, with a radius  $AD$ , describe the arc  $AB$ . The line  $AC$  is tangent to this arc at the point  $A$ .

(621)  $AB$  in Fig. 60 is the given line,  $C$  the given point,  $CD = CE$ .

From  $D$  and  $E$  as centers with the same radii, describe arcs intersecting at  $F$ . Through  $F$  draw  $CG$ . Lay off  $CG$  and  $CB$  equal to each other, and from  $B$  and  $G$  as centers with equal radii describe arcs intersecting at  $H$ . Draw  $CH$ . The

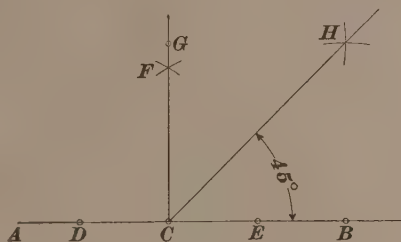


FIG. 60.

angle  $BCH = 45^\circ$ .

(622) 1st.  $AB$  in Fig. 61 is the given line 3 in. long. At  $A$  and  $B$  erect perpendiculars  $AC$  and  $BD$  each 3 in.

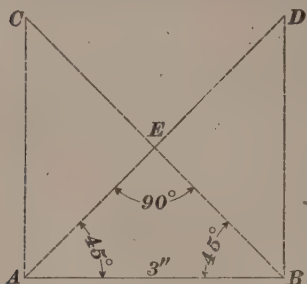


FIG. 61.

long. Join  $AD$  and  $BC$ . These lines will intersect at some point  $E$ . The angles  $EAB$  and  $EBA$  are each  $45^\circ$ , and the sides  $AE$  and  $EB$  must be equal, and the angle  $AEB = 90^\circ$ .

2d.  $AB$  in Fig. 62 is the given line and  $c$  its middle point. On  $AB$  describe the semicircle  $AEB$ . At  $c$  erect a perpendicular to  $AB$ , cutting the arc  $AEB$  in  $E$ . Join  $AE$  and  $EB$ . The angle  $AEB$  is  $90^\circ$ .

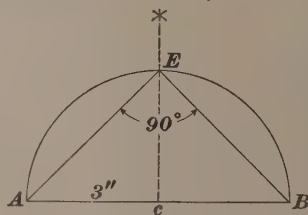


FIG. 62.

(623) See Art. 1181 and Fig. 237.

(624) See Art. 1187.

(625) (See Art. 1195 and Fig. 245.) Draw the line  $AB$ , Fig. 63, 5 in. long, the length of the given side. At  $A$  draw the indefinite line  $AC$ , making the angle  $BAC$

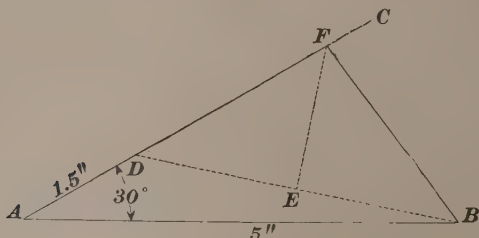


FIG. 63.

equal to the given angle of  $30^\circ$ . On  $AC$  lay off  $AD$  1.5 in. long, the given difference between the other two sides of

the triangle. Join the points  $B$  and  $D$  by a straight line, and at its middle point  $E$  erect a perpendicular, cutting the line  $A C$  in the point  $F$ . Join  $B F$ . The triangle  $A B F$  is the required triangle.

(626) See Art. 1198.

(627) See Art. 1200.

(628) See Art. 1201.

(629) See Art. 1204.

(630) See Art. 1205.

(631) See Arts. 1205 and 1206.

(632) See Art. 1206.

(633) See Art. 1204.

(634) See Art. 1207.

(635) See Art. 1207.

(636) See Arts. 1209 and 1213.

(637) See Art. 1211.

(638) (a) In this example the *declination* is *cast*, and

| Magnetic<br>Bearing. | True<br>Bearing. |
|----------------------|------------------|
| N 15° 20' E          | N 18° 35' E      |
| N 88° 50' E          | S 87° 55' E      |
| N 20° 40' W          | N 17° 25' W      |
| N 50° 20' E          | N 53° 35' E      |

for a course whose *magnetic bearing* is N E or S W, the

*true bearing* is the *sum* of the magnetic bearing and the declination. For a course whose *magnetic bearing* is N W or S E, the *true bearing* is the difference between the magnetic bearing and the declination.

As the first magnetic bearing is N  $15^{\circ} 20'$  E, the true bearing is the *sum* of the *magnetic bearing* and the *declination*. We accordingly make the addition as follows:

$$\begin{array}{r} \text{N } 15^{\circ} 20' \text{ E} \\ \quad 3^{\circ} 15' \\ \hline \text{N } 18^{\circ} 35' \text{ E,} \end{array}$$

and we have N  $18^{\circ} 35'$  E as the true bearing of the first course.

The second magnetic bearing is N  $88^{\circ} 50'$  E, and we add the declination of  $3^{\circ} 15'$  to that bearing, giving N  $92^{\circ} 05'$  E. This takes us past the east point to an amount equal to the *difference* between  $90^{\circ}$  and  $92^{\circ} 05'$ , which is  $2^{\circ} 05'$ . This angle we *subtract* from  $90^{\circ}$ , the total number of degrees between the south and east points, giving us S  $87^{\circ} 55'$  E for the *true bearing* of our line. A simpler method of determining the true bearing, when the sum of the magnetic bearing and the declination exceeds  $90^{\circ}$ , is to subtract that sum from  $180^{\circ}$ ; the difference is the true bearing. Applying this method to the above example, we have  $180^{\circ} - 92^{\circ} 05' = \text{S } 87^{\circ} 55' \text{ E}$ .

The third magnetic bearing is N  $20^{\circ} 30'$  W, and the *true bearing* is the *difference* between that bearing and the declination. We accordingly deduct from the magnetic bearing N  $20^{\circ} 40'$  W, the declination  $3^{\circ} 15'$ , which gives N  $17^{\circ} 25'$  W for the true bearing.

(b) Here the *declination* is *west*, and for a course whose *magnetic bearing* is N W or S E the *true bearing* is the *sum* of the magnetic bearing and the declination. For a course whose *magnetic bearing* is N E or S W, the *true bearing* is the *difference* between the magnetic bearing and the declination.



The first magnetic bearing is  $N\ 7^{\circ}\ 20'\ W$ , and as the declination is west, it will be added. We, therefore, have for the true bearing  $N\ 7^{\circ}\ 20'\ W + 5^{\circ}\ 10' = N\ 12^{\circ}\ 30'\ W$ .

| Magnetic Bearing.       | True Bearing.           |
|-------------------------|-------------------------|
| $N\ 7^{\circ}\ 20'\ W$  | $N\ 12^{\circ}\ 30'\ W$ |
| $N\ 45^{\circ}\ 00'\ E$ | $N\ 39^{\circ}\ 50'\ E$ |
| $S\ 15^{\circ}\ 20'\ E$ | $S\ 20^{\circ}\ 30'\ E$ |
| $S\ 2^{\circ}\ 30'\ W$  | $S\ 2^{\circ}\ 40'\ E$  |

The next two bearings the student can readily determine for himself.

The fourth magnetic bearing is  $S\ 2^{\circ}\ 30'\ W$ , and to obtain the true bearing we must *subtract* the declination, i. e., we must change the direction eastwards. A change of  $2^{\circ}\ 30'$  will bring us *due south*; hence, the bearing will be east of south to an amount equal to the difference between  $2^{\circ}\ 30'$  and the total declination  $5^{\circ}\ 10'$ , which is  $2^{\circ}\ 40'$ . The true bearing is, therefore,  $S\ 2^{\circ}\ 40'\ E$ .

**(639)** See Art. 1216.

**(640)** See Art. 1217.

**(641)** See Art. 1219.

**(642)** A plat of the accompanying notes is given in Fig. 64 to a scale of 600 ft. to the inch. The order of work is as follows:

First draw a meridian  $NS$  (see Fig. 64), and then assume the starting point  $A$ , which call Sta. 0. Through  $A$  draw a meridian  $AB$  parallel to  $NS$ . Then, placing the center of the protractor at  $A$ , with its zero point in the line  $AB$ , lay off the bearing angle  $10^{\circ}\ 10'$  to the right of

$A B$ , as the bearing is N E. Mark the point of angle measurement carefully, and draw a line joining it and the point  $A$ . This line will give the direction of the first course, the end of which is at Sta.  $5 + 20$ , giving 520 ft. for the length of that course. On this line lay off to a scale of 600 ft. to the inch the distance 520 ft., locating the point  $C$ , which is Sta.  $5 + 20$ . Through  $C$  draw a meridian  $C D$ , and with the protractor lay off the bearing angle N  $40^{\circ} 50'$  E to the right of the meridian, marking the point of angle measurement and joining it with the point  $C$  by a straight line, which will be the direction of the second course. The end of this course is Sta.  $10 + 89$ , and its length is the difference between 1,089 and 520, which is -

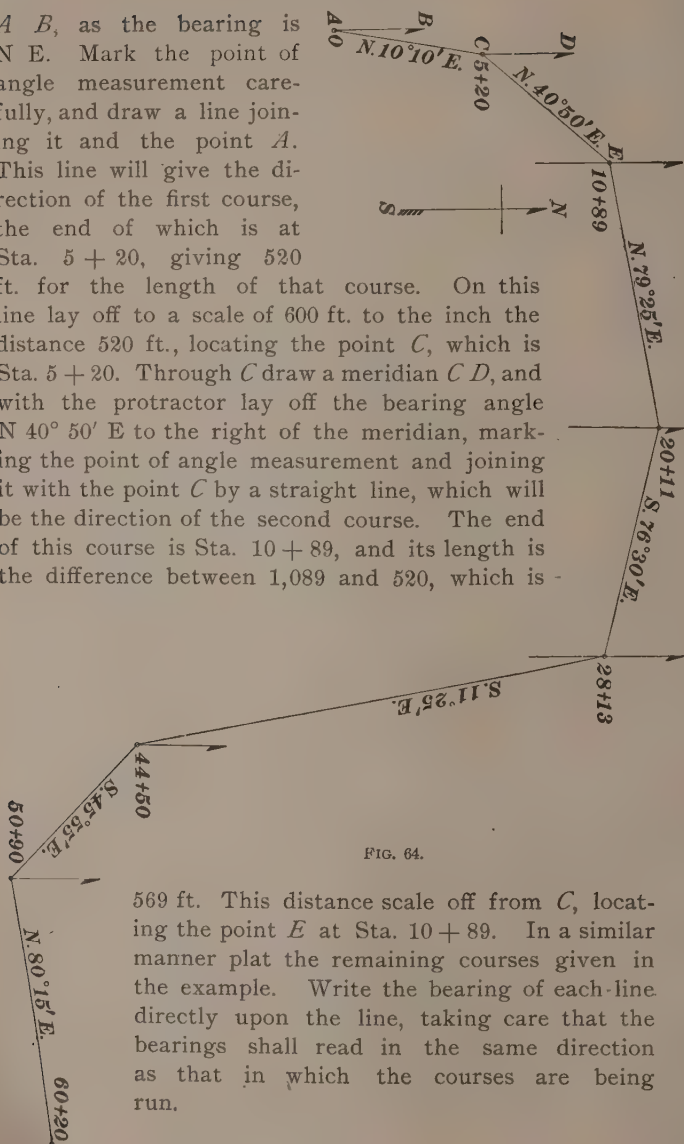


FIG. 64.

569 ft. This distance scale off from  $C$ , locating the point  $E$  at Sta.  $10 + 89$ . In a similar manner plot the remaining courses given in the example. Write the bearing of each line directly upon the line, taking care that the bearings shall read in the same direction as that in which the courses are being run.

(643) See Art. **1231** and Figs. 261 and 262.

(644) For *first* adjustment see Art. **1233**. For *second* adjustment see Art. **1234** and Fig. 263, and for *third* adjustment see Art. **1235** and Fig. 264.

(645) See Art. **1238** and Fig. 265.

(646) See Art. **1239** and Fig. 266.

(647) See Art. **1240** and Fig. 267.

(648) See Art. **1242** and Fig. 269.

(649) See Art. **1242** and Fig. 269.

(650) To the bearing at the given line, viz., N  $55^{\circ} 15'$  E, we add the angle  $15^{\circ} 17'$ , which is turned to the right. This gives for the second line a bearing of N  $70^{\circ} 32'$  E.

(651) To the bearing of the given line, viz., N  $80^{\circ} 11'$ , we add the angle  $22^{\circ} 13'$ , which is the amount of change in the direction of the line. The sum is  $102^{\circ} 24'$ , and the direction is  $102^{\circ} 24'$  to the *right* or *east* of the *north* point of the compass. At  $90^{\circ}$  to the right of north the direction is due east. Consequently, the direction of the second line must be *south* of east to an amount equal to the difference between  $102^{\circ} 24'$  and  $90^{\circ}$ , which is  $12^{\circ} 24'$ . Subtracting this angle from  $90^{\circ}$ , the angle between the south and east points, we have  $77^{\circ} 36'$ , and the direction of the second line is S  $77^{\circ} 36'$  E. The simplest method of determining the direction of the second line is to subtract  $102^{\circ} 24'$  from  $180^{\circ} 00'$ . The difference is  $77^{\circ} 36'$ , and the direction changing from N E to S E gives for the second line a bearing of S  $77^{\circ} 36'$  E.

(652) To the bearing of the given line, viz., N  $13^{\circ} 15'$  W, we add the angle  $40^{\circ} 20'$ , which is turned to the left. The sum is  $53^{\circ} 35'$ , which gives for the second line a bearing of N  $53^{\circ} 35'$  W.

(653) The bearing of the first course, viz., S  $10^{\circ} 15'$  W, is found in the column headed Mag. Bearing, opposite Sta. 0. For the first course, the deduced or calculated bearing must be the same as the magnetic bearing. At Sta. 4 + 40,

an angle of  $15^{\circ} 10'$  is turned to the right. It is at once evident that if a person is traveling in the direction  $S 10^{\circ} 15' W$ , and changes his course to the right  $15^{\circ} 10'$ , his course will approach a due westerly direction by the amount of the change, and the direction of his second course is found by adding to the first course, viz.,  $S 10^{\circ} 15'$ , the amount of such

| Station. | Deflection.         | Mag. Bearing.        | Ded. Bearing.        |
|----------|---------------------|----------------------|----------------------|
| 54 + 25  |                     |                      |                      |
| 49 + 20  | L. $25^{\circ} 14'$ | S $25^{\circ} 40' W$ | S $25^{\circ} 39' W$ |
| 44 + 80  | L. $10^{\circ} 47'$ | S $50^{\circ} 50' W$ | S $50^{\circ} 53' W$ |
| 33 + 77  | R. $16^{\circ} 55'$ | S $61^{\circ} 45' W$ | S $61^{\circ} 40' W$ |
| 25 + 60  | R. $24^{\circ} 40'$ | S $44^{\circ} 50' W$ | S $44^{\circ} 45' W$ |
| 16 + 20  | L. $15^{\circ} 35'$ | S $20^{\circ} 00' W$ | S $20^{\circ} 05' W$ |
| 8 + 90   | R. $10^{\circ} 15'$ | S $35^{\circ} 50' W$ | S $35^{\circ} 40' W$ |
| 4 + 40   | R. $15^{\circ} 10'$ | S $25^{\circ} 20' W$ | S $25^{\circ} 25' W$ |
| 0        |                     | S $10^{\circ} 15' W$ | S $10^{\circ} 15' W$ |

change in direction. The sum is  $25^{\circ} 25'$ , and the second course  $S 25^{\circ} 25' W$ . The needle at this point reads  $S 25^{\circ} 20' W$ . The difference between the magnetic bearing and the calculated bearing may be owing to local attraction, but as we can not read the needle to within 10 minutes, we must generally ascribe small discrepancies to that cause. This calculated bearing we write in its proper column opposite Sta. 4 + 40, where the change in direction occurred.

The next angle is  $10^{\circ} 15'$  to the right, which we add to the previous calculated bearing  $S 25^{\circ} 25' W$ , giving  $S 35^{\circ} 40' W$  for the calculated bearing of the third course, which extends from Sta. 8 + 90 to 16 + 20. In a similar manner, the student will calculate the remaining bearings, considering well how the changes in direction will affect his relations to the points of the compass. A plat of the notes to a scale of 400 ft. to the inch is given in Fig. 65.

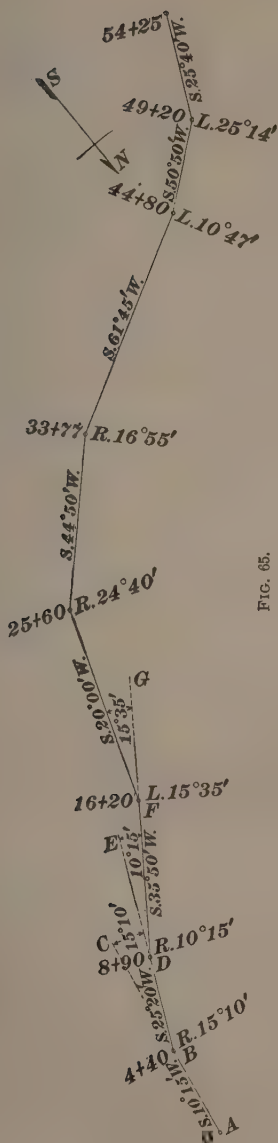


FIG. 65.

Assume the starting point *A*, Fig. 65, which is Sta. 0, and through it draw a straight line. The first angle, viz.,  $15^{\circ} 10'$  to the right, is turned at Sta.  $4 + 40$ , giving for the first course a length of 440 ft. Scale off this distance from *O A* to a scale of 400 ft. to the inch, locating the point *B*, which is Sta.  $4 + 40$ , and write on the line its bearing S  $10^{\circ} 15' W$ , as recorded in the notes. Produce *A B* to *C*, making *B C* greater than the diameter of the protractor, and from *B* lay off to the right of *B C* the angle  $15^{\circ} 10'$ . Join this point of angle measurement with *B* by a straight line, giving the direction of the second course. The end of this course is at Sta.  $8 + 90$ , and its length is the difference between  $8 + 90$  and  $4 + 40$ , which is 450 ft. This distance we scale off from *B*, Sta.  $4 + 40$ , locating the point *D*, and write on the line its bearing of S  $25^{\circ} 20' W$ , as found in the notes. We next produce *B D* to *E*, making *D E* greater than the diameter of the protractor, and at *D* lay off the angle  $10^{\circ} 15'$  to the right of *D E*, giving the direction of the next course. In a similar manner, plat the remaining notes given in Example 653. The student in his drawing will show the prolongation of only the first three lines, drawing such prolongations



in dotted lines. In platting the remaining angles, he will produce the lines in pencil only, erasing them as soon as the forward angle is laid off. Write the proper station number in pencil at the end of each line as soon as platted, and the angle with its direction, R. or L., before laying off the following angle. Write the bearing of each line distinctly, the letters reading in the same direction in which the line is being run. The magnetic meridian is platted as follows: The bearing of the course from Sta. 33 + 77 to Sta. 44 + 80 is S 61° 45' W, i. e., the course is 61° 45' to the left of a north and south line, which is the direction we wish to indicate on the map. Accordingly, we place a protractor with its center at Sta. 33 + 77 and its zero on the following course, and read off the angle 61° 45' to the right. Through this point of angle measurement and Sta. 33 + 77 draw a straight line N S. This line is the required meridian.

(654) Angle  $B = 39^\circ 25'$ . From the principles of trigonometry (see Art. 1243), we have the following proportion:

$$\sin 39^\circ 25' : \sin 60^\circ 15' :: 415 \text{ ft.} : \text{side } A B.$$

$$\sin 60^\circ 15' = .8682.$$

$$415 \text{ ft.} \times .8682 = 360.303 \text{ ft.}$$

$$\sin 39^\circ 25' = .63496.$$

$$360.303 \div .63496 = 567.442 \text{ ft., the side } A B. \text{ Ans.}$$

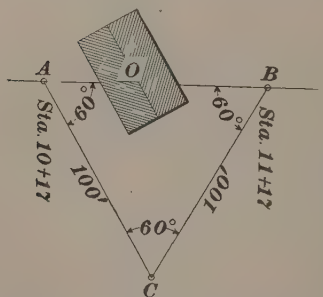


FIG. 66.

(655). (See Fig. 66.) At  $A$  we turn an angle  $BAC$  of  $60^\circ$  and set a plug at  $C$  100' from  $A$ . At  $C$  we turn an angle  $ACB$  of  $60^\circ$  and set a plug at  $B$  100' from  $C$ . The point  $B$  will be in the line  $AB$ , and setting up the instrument at  $B$ , we turn the angle  $CBA = 60^\circ$ . The instrument is then reversed,

and the line  $AB$  produced as required.

(656) See Art. 1245.

(657) See Art. 1246.

(658) See Art. 1246.

(659) See Art. 1248.

(660) See Art. 1249.

(661) A  $5^\circ$  curve is one in which a central angle of  $5^\circ$  will subtend a chord of 100 ft. at its circumference. Its radius is practically one-fifth of the radius of a  $1^\circ$  curve, and equal to  $5,730 \text{ ft.} \div 5 = 1,146 \text{ ft.}$

(662) The degree of curve is always twice as great as the deflection angle for a chord of 100 feet.

(663) See Art. 1249 and Fig. 282.

(664) Formula 90,  $C = 2 R \sin D$ . (See Art. 1250.)

(665) Formula 91,  $T = R \tan \frac{1}{2} I$ . (See Art. 1251.)

(666) The intersection angle  $CEF$ , being external to the triangle  $AEC$ , is equal to the sum of the opposite interior angles  $A$  and  $C$ .  $A = 22^\circ 10'$  and  $C = 23^\circ 15'$ . Their sum is  $45^\circ 25' = CEF$ . Ans.

The angle  $AEC = 180^\circ - (22^\circ 10' + 23^\circ 15') = 134^\circ 35'$ .

From the principles of trigonometry (see Art. 1243), we have

$$\sin 134^\circ 35' : \sin 23^\circ 15' :: 253.4 \text{ ft.} : \text{side } AE;$$

$$\text{whence, side } AE = 140.44 \text{ ft., nearly. Ans.}$$

$$\text{Also, } \sin 134^\circ 35' : \sin 22^\circ 10' :: 253.4 \text{ ft.} : \text{side } CE;$$

$$\text{whence, side } CE = 134.24 \text{ ft., nearly. Ans.}$$

(667) We find the tangent distance  $T$  by applying formula 91,  $T = R \tan \frac{1}{2} I$ . (See Art. 1251.) From the table of Radii and Deflections we find the radius of a  $6^\circ 15'$  curve = 917.19 ft.;  $\frac{1}{2} I = \frac{35^\circ 10'}{2} = 17^\circ 35'$ ;  $\tan 17^\circ 35' = .3169$ . Substituting these values in the formula, we have  $T = 917.19 \times .3169 = 290.66 \text{ ft.}$  Ans.

(668) We find the tangent distance  $T$  by applying formula 91,  $T = R \tan \frac{1}{2} I$ . (See Art. 1251.) From the

table of Radii and Deflections we find the radius of a  $3^{\circ} 15'$  curve is 1,763.18 ft.;  $\frac{1}{2} I = \frac{14^{\circ} 12'}{2} = 7^{\circ} 06'$ ;  $\tan 7^{\circ} 06' = .12456$ . Substituting these values in the above formula, we have  $T = 1,763 \times .12456 = 219.62$  ft. Ans.

(669) See Art. 1252.

(670) The angle of intersection  $30^{\circ} 45'$ , reduced to decimal form, is  $30.75^{\circ}$ . The degree of curve  $5^{\circ} 15'$ , reduced to decimal form, is  $5.25^{\circ}$ . Dividing the intersection angle  $30.75^{\circ}$  by the degree of curve 5.25 (see Art. 1252), the quotient is the required length of the curve in stations of 100 ft. each.  $\frac{30.75^{\circ}}{5.25^{\circ}} = 5.8571$  full stations equal to 585.71 ft.

(671) In order to determine the P. C. of the curve, we must know the tangent distance which, subtracted from the number of the station of the intersection point, will give us the P. C. We find the tangent distance  $T$  by applying formula 91,  $T = R \tan \frac{1}{2} I$ . (See Art. 1251.) From the table of Radii and Deflections we find the radius of a  $5^{\circ}$  curve is 1,146.28 ft.;  $\frac{1}{2} I = \frac{33^{\circ} 06'}{2} = 16^{\circ} 33'$ ;  $\tan 16^{\circ} 33' = .29716$ .

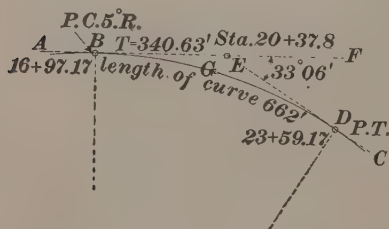


FIG. 67.

Substituting these values in formula 91, we have  $T = 1,146.28 \times .29716 = 340.63$  ft. In Fig. 67, let  $AB$  and  $CD$  be the tangents which intersect in the point  $E$ , forming an angle  $DEF = 33^{\circ} 06'$ .

The line of survey is being run in the direction  $AB$ , and the line is measured in regular order up to the intersection point  $E$ , the station of which is  $20 + 37.8$ . Subtracting the tangent distance,  $BE = 340.63$  ft. from  $\text{Sta. } 20 + 37.8$ , we have  $16 + 97.17$ , the station of the P. C. at  $B$ . The intersection angle  $33^{\circ} 06'$  in decimal form is  $33.1^{\circ}$ . Dividing

this angle by 5, the degree of the curve, we obtain the length  $BGD$  of the curve in full stations.  $\frac{33.1}{5} = 6.62$  stations = 662 ft. The length of the curve, 662 ft., added to the station of the P. C., viz.,  $16 + 97.17$ , gives  $23 + 59.17$ , the station of the P. T. at  $D$ .

(672) The given tangent distance, viz., 291.16 ft., was obtained by applying formula **91**,  $T = R \tan \frac{1}{2} I$  (see Art. **1251**),  $I = 20^\circ 10'$ , and  $\frac{1}{2} I = 10^\circ 05'$ ,  $\tan 10^\circ 05' = .17783$ . Substituting these values in the above formula, we have  $291.16 = R \times .17783$ ; whence,  $R = \frac{291.16}{.17783} = 1,637.29$  ft. Ans.

The degree of curve corresponding to the radius 1,637.29 we determined by substituting the radius in formula **89**,  $R = \frac{50}{\sin D}$  (see Art. **1249**), and we have

$$1,637.29 = \frac{50}{\sin D}; \text{ whence, } \sin D = \frac{50}{1,637.29} = .03054.$$

The deflection angle corresponding to the sine .03054 is  $1^\circ 45'$ , and is one-half the degree of the curve. The degree of curve is, therefore,  $1^\circ 45' \times 2 = 3^\circ 30'$ . Ans.

(673) Formula **92**,  $d = \frac{c^2}{R}$ . (See Art. **1255** and Fig. 283.)

(674) The ratio is 2; i. e., the chord deflection is double the tangent deflection. (See Art. **1254** and Fig. 283.)

(675) As the degree of the curve is  $7^\circ$ , the deflection angle is  $3^\circ 30' = 210'$  for a chord of 100 ft., and for a chord of 1 ft. the deflection angle is  $\frac{210'}{100} = 2.1'$ ; and for a chord of 48.2 ft. the deflection angle is  $48.2 \times 2.1' = 101.22' = 1^\circ 41.22'$ .

(676) The deflection angle for 100-ft. chord is  $\frac{6^\circ 15'}{2} = 3^\circ 07\frac{1}{2}' = 187.5'$ , and the deflection angle for a 1-ft. chord is

$\frac{187.5'}{100} = 1.875'$ . The deflection angle for a chord of 72.7 ft. is, therefore,  $1.875' \times 72.7 = 136.31' = 2^\circ 16.31'$ .

(677) We find the tangent deflection by applying formula 93,  $\tan \text{ def.} = \frac{c^2}{2R}$ . (See Art. 1255.)  $c = 50$ .  $50^2 = 2,500$ . The radius  $R$  of  $5^\circ 30'$  curve  $= 1,042.14$  ft. (See table of Radii and Deflections.) Substituting these values in formula 93, we have  $\tan \text{ def.} = \frac{2,500}{2,084.28} = 1.199$  ft. Ans.

(678) The formula for chord deflections is  $d = \frac{c^2}{R}$ . (See Art. 1255, formula 92.)  $c = 35.2$ .  $35.2^2 = 1,239.04$ . The radius  $R$  of a  $4^\circ 15'$  curve is 1,348.45 ft. Substituting these values in formula 92, we have  $d = \frac{1,239.04}{1,348.45} = .919$  ft. Ans.

(679) The formula for finding the radius  $R$  is  $R = \frac{50}{\sin D}$ . (See Art. 1249.) The degree of curve is  $3^\circ 10'$ .  $D$ , the deflection angle, is  $\frac{3^\circ 10'}{2} = 1^\circ 35'$ ;  $\sin 1^\circ 35' = .02763$ . Substituting the value of  $\sin D$  in the formula, we have  $R = \frac{50}{.02763}$ ; whence,  $R = 1,809.63$  ft. Ans.

The answer given with the question, viz., 1,809.57 ft., agrees with the radius given in the table of Radii and Deflections, which was probably calculated with sine given to eight places instead of five places, as in the above calculation, which accounts for the discrepancy in results.

(680) In Fig. 68, let  $AB$  and  $AC$  represent the given lines, and  $BC$  the amount of their divergence, viz., 18.22 ft. The lines will form a triangle  $ABC$ , of which the angle  $A = 1^\circ$ . Draw a perpendicular from  $A$  to  $D$ , the middle point of the base. The perpendicular will

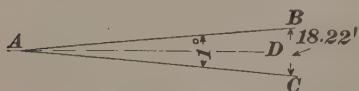


FIG. 68.



bisect the angle  $A$  and form two right angles at the base of the triangle. In the triangle  $ADB$  we have, from rule 3,

$$\text{Art. 754, } \tan BAD = \frac{BD}{AD}. \quad BAD = 30', \quad BD = \frac{18.22 \text{ ft.}}{2} =$$

9.11 ft., and  $\tan 30' = .00873$ . Substituting known values

$$\text{in the equation, we have } .00873 = \frac{9.11}{AD}; \text{ whence, } AD =$$

$$\frac{9.11 \text{ ft.}}{.00873} = 1,043.53 \text{ ft.} \quad \text{Ans.}$$

By a practical method, we determine the length of the lines by the following proportion:

$$1.745 : 18.22 :: 100 \text{ ft.} : \text{the required length of line;}$$

$$\text{whence, length of line} = \frac{1,822}{1.745} = 1,044.13 \text{ ft.} \quad \text{Ans.}$$

The second result is an application of the principle of two lines 100 ft. in length forming an angle of  $1^\circ$  with each other, which will at their extremity diverge 1.745 ft.

$$(681) \quad \text{Degree of curve} = \frac{24^\circ 15'}{6.0625} = \frac{24.25^\circ}{6.0625} = 4^\circ. \quad \text{Ans.}$$

$$(682) \quad \text{See Arts. 1264, 1265, 1266, and 1267.}$$

$$(683) \quad \text{See Arts. 1269-1274.}$$

(684) Denote the radius of the bubble tube by  $x$ ; the distance of the rod from the instrument, viz., 300', by  $d$ ; the difference of rod readings, .03 ft., by  $h$ , and the movement of the bubble, viz., .01 ft., by  $S$ . By reference to Art. 1275 and Fig. 289, we will find that the above values have the proportion  $h : S :: d : x$ . Substituting known values in the proportion, we have  $.03 : .01 :: 300 : x$ ; whence,

$$x = \frac{3}{.03} = 100 \text{ ft., the required radius.} \quad \text{Ans.}$$

$$(685) \quad \text{See Art. 1277.}$$

$$(686) \quad \text{See Art. 1278.}$$

(687) To the elevation 61.84 ft. of the given point, we add 11.81 ft., the backsight. Their sum, 73.65 ft., is the height of instrument. From this H. I., we subtract the fore-

sight to the T. P., viz., 0.49 ft., leaving a difference of 73.16 ft., which is the elevation of the T. P. (See Art. 1279.)

(688) See Art. 1280.

(689) See Art. 1281.

(690) See Art. 1282.

(691) See Art. 1286.

(692) See Art. 1289.

(693) See Art. 1290.

(694) See Art. 1291.

(695) The distance between Sta. 66 and Sta. 93 is 27 stations. As the rate of grade is + 1.25 ft. per station, the total rise in the given distance is 1.25 ft.  $\times$  27 = 33.75 ft., which we add to 126.5 ft., the grade at Sta. 66, giving 160.25 ft. for the grade at Sta. 93. (See Art. 1291.)

(696) See Art. 1292.

$$(697) \quad \begin{array}{r} -16.4' \\ \hline 56' \end{array} \quad \begin{array}{r} -10.3' \\ \hline 73' \end{array} \quad \left| \begin{array}{r} +11.4' \\ \hline 84' \end{array} \quad \begin{array}{r} +8.8' \\ \hline 96' \end{array} \right.$$

Contour 50.0 at 46.0 ft. to left of Center Line.

Contour 40.0 at 94.0 ft. to left of Center Line.

Contour 30.0 at 128.0 ft. to left of Center Line.

Contour 60.0 at 26 ft. to right of Center Line.

Contour 70.0 at 106.9 ft. to right of Center Line.

Elevation 76.7 at 180 ft. to right of Center Line.

(698) The elevations of the accompanying level notes are worked out as follows: The first elevation recorded in the column of elevations is that of the *bench mark*, abbreviated to B. M. This elevation is 161.42 ft. The first rod reading, 5.53 ft., is the backsight on this B. M., a *plus* reading, and recorded in column of rod readings. This rod reading we add to the elevation of the bench mark, to determine the height of instrument, as follows: 161.42 ft. + 5.53 ft. = 166.95 ft., the H. I. The next rod reading, which is at Sta. 40, is 6.4 ft. The rod reading means that the surface of the ground at Sta. 40 is 6.4 ft. below the horizontal axis of the telescope. The elevation of that surface is, therefore, the difference between 166.95 ft., the H. I., and 6.4 ft., the rod reading.  $166.95 - 6.4 = 160.55$  ft. The  $\frac{5}{100}$  ft. is a

fraction so small that in surface elevations it is the universal practice to ignore it, and the elevation of the ground at

| Station. | Rod Reading. | Height Instrument. | Elevation. | Grade.  |
|----------|--------------|--------------------|------------|---------|
| B. M.    | + 5.53       | 166.95             | 161.42     |         |
| 40       | 6.4          |                    | 160.5      | 162.0   |
| 41       | 7.2          |                    | 159.7      | 160.485 |
| 41 + 60  | 10.9         |                    | 156.0      |         |
| 42       | 8.6          |                    | 158.3      | 158.97  |
| 43       | 8.8          |                    | 158.1      | 157.455 |
| T. P. —  | 8.66         |                    | 158.29     |         |
| +        | 2.22         | 160.51             |            |         |
| 44       | 4.8          |                    | 155.7      | 155.94  |
| 45       | 6.3          |                    | 154.2      | 154.425 |
| 46       | 8.8          |                    | 151.7      | 152.91  |
| 47       | 9.9          |                    | 150.6      | 151.395 |
| 48       | 11.1         |                    | 149.4      | 149.88  |
| T. P. —  | 11.24        |                    | 149.27     |         |
| +        | 3.30         | 152.57             |            |         |
| 49       | 4.7          |                    | 147.9      | 148.365 |
| 50       | 7.1          |                    | 145.5      | 146.85  |
| 51       | 8.7          |                    | 143.9      | 145.335 |
| 52       | 9.8          |                    | 142.8      | 143.82  |
| 53       | 10.9         |                    | 141.7      | 142.305 |
| T. P. —  | 11.62        |                    | 140.95     |         |

Sta. 40 is taken at 160.5 ft. The rod reading at Sta. 41 is 7.2, which, subtracted from 166.95 ft., gives for that station an elevation of 159.7. The remaining rod readings up to

and including that at Sta. 43, we subtract from the same H. I., viz., 166.95. Here at a turning point (T. P.) of 8.66 ft. is taken and recorded in the column of rod readings. This reading being a foresight is *minus*, and is subtracted from the preceding H. I. This gives us for the elevation of the T. P.,  $166.95 \text{ ft.} - 8.66 \text{ ft.} = 158.29 \text{ ft.}$ , which we record in the column of elevations. The instrument is then moved forwards and a backsight of 2.22 ft. taken on the same T. P. and recorded in the column. This is a *plus* reading, and is added to the elevation of the T. P., giving us for the next H. I. an elevation of  $158.29 \text{ ft.} + 2.22 \text{ ft.} = 160.51 \text{ ft.}$  The next rod reading, viz., 4.8, is at Sta. 44, and the elevation at that station is the difference between the preceding H. I., 160.51, and that rod reading, giving an elevation of  $160.51 \text{ ft.} - 4.8 \text{ ft.} = 155.7 \text{ ft.}$ , which is recorded in the column of elevations opposite Sta. 44. In a similar manner, the remaining elevations are determined.

In checking level notes, only the *turning points* rod readings are considered. It will be evident that starting from a given bench mark, all the *backsight* or *plus* readings will add to that elevation, and all the *foresight* or *minus* readings will subtract from that elevation. If now we place in one column the height of the B. M., together with all the backsight or + readings, and in another column all the foresight or - readings, and find the sum of each column, then, by subtracting the sum of the - readings from the sum of the + readings, we shall find the elevation of the last point calculated, whether it be a turning point or a height of instrument. Applying this method to the foregoing notes we have the following:

|       | + readings.      | - readings. |
|-------|------------------|-------------|
| B. M. | 161.42 ft.       | 8.66 ft.    |
|       | 5.53 ft.         | 11.24 ft.   |
|       | 2.22 ft.         | 11.62 ft.   |
|       | 3.30 ft.         | 31.52 ft.   |
|       | <hr/> 172.47 ft. |             |
|       | 31.52 ft.        |             |
|       | <hr/> 140.95 ft. |             |

The difference of the columns, viz., 140.95 ft., agrees with the elevation of the T. P. following Sta. 53, which is the last one determined. A check mark  $\checkmark$  is placed opposite the elevation checked, to show that the figures have been verified. The rate of grade is determined as follows: In one mile there are 5,280 ft. = 52.8 stations. A descending grade of 80 ft. per mile gives per station a descent of  $\frac{80 \text{ ft.}}{52.8} = 1.515$  ft. The elevation of the grade at Sta. 40 is fixed at 162.0 ft. As the grade descends from Sta. 40 at the rate of 1.515 ft. per station, the grade at Sta. 41 is found by subtracting 1.515 ft. from 162.0 ft., which gives 160.485 ft., and the grade for each succeeding station is found by subtracting the rate of grade from the grade of the immediately preceding station.

A section of profile paper is given in Fig. 69 in which the level notes are plotted, and upon which the given grade line

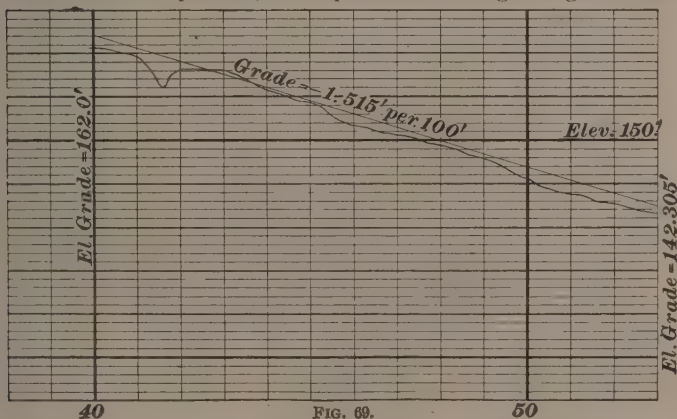


FIG. 69.

is drawn. The profile is made to the following scales: viz., horizontal, 400 ft. = 1 in.; vertical, 20 ft. = 1 in.

Every fifth horizontal line is heavier than the rest, and each twenty-fifth horizontal line is of *double weight*. Every tenth vertical line is of *double weight*. The spaces between the vertical lines represent 100 ft., and those between the

horizontal lines 1 ft. The figure represents 1,500 ft. in length and 45 ft. in height. Assume the elevation of the sixth heavy line from the bottom at 150 ft. The second vertical line from the left of the figure is Sta. 40, which is written in the margin at the bottom of the page. Under the next heavy vertical line, ten spaces to the right, Sta. 50 is written. The elevation of Sta. 40, as recorded in the notes, is 160.5 ft. We determine the corresponding elevation in the profile as follows:

As the elevation of the sixth heavy line from the bottom is assumed at 150 ft., 160.5 ft., which is 10.5 ft. higher, must be  $10\frac{1}{2}$  spaces above this line. This additional space covers two heavy lines and one-half the next space. This point is marked in pencil. The elevation of Sta. 41, viz., 159.7 ft., we locate on the next vertical line and 9.7 spaces above the 150 ft. line. The next elevation, 156.0 ft., is at Sta. 41 + 60. This distance of 60 ft. from Sta. 41 we estimate by the eye and plat the elevation in its proper place. In a similar manner, we plat the remaining elevations and connect the points of elevation by a continuous line drawn free-hand. The grade at Sta. 40 is 162.0 ft. This elevation should be marked in the profile by a point enclosed by a small circle. At each station between Sta. 40 and Sta. 53 there has been a descent of 1.515 ft., making a total descent between these stations of  $1.515 \times 13 = 19.695$ . The grade at Sta. 53 will, therefore, be 162.0 ft. - 19.695 ft. = 142.305 ft. Plat the elevation in the profile at Sta. 53, and enclose the point in a small circle. Join the grade point at Sta. 40 with that at Sta. 53 by a straight line, which will be the grade line required. Upon this line mark the grade - 1.515 per 100 ft.

$$(699) \quad \frac{-5^{\circ}}{65'} \quad \frac{-9^{\circ}}{117'} \quad \left| \quad \frac{+11^{\circ}}{120'}$$

Nine 5-foot contours are included within the given slopes, as follows:

|                                                     |                                                      |
|-----------------------------------------------------|------------------------------------------------------|
| Contour 70.0 at 32.0 ft. to left of Center Line.    | Contour 80.0 at 26.0 ft. to right of Center Line.    |
| Contour 65.0 at 64.0 ft. to left of Center Line.    | Contour 85.0 at 52.0 ft. to right of Center Line.    |
| Contour 60.0 at 96.0 ft. to left of Center Line.    | Contour 90.0 at 78.0 ft. to right of Center Line.    |
| Contour 55.0 at 128.0 ft. to left of Center Line.   | Contour 95.0 at 104.0 ft. to right of Center Line.   |
| Elevation 51.0 at 182.0 ft. to left of Center Line. | Elevation 98.1 at 120.0 ft. to right of Center Line. |



(700)  $1.745 \text{ ft.} \times 3 = 5.235 \text{ ft.}$ , the vertical rise of a  $3^\circ$  slope in 100 ft., or 1 station and  $\frac{10}{5.235} = 1.91 \text{ stations} = 191 \text{ ft.}$

(701) (See Question 701, Fig. 15.) From the instrument to the center of the spire is  $100 \text{ ft.} + 15 = 115 \text{ ft.}$ , and we have a right triangle whose base  $AD = 115 \text{ ft.}$  and angle  $A$  is  $45^\circ 20'$ . From rule 5, Art. 754, we have  $\tan 45^\circ 20' = \frac{\text{side } BD}{115}$ ; whence,  $1.01170 = \frac{\text{side } BD}{115}$ ; or  $BD = 116.345$  feet. The instrument is 5 feet above the level of the base; hence,  $116.345 \text{ ft.} + 5 \text{ ft.} = 121.345$ , the height of the spire.

(702) Apply formula 96.

$$Z = (\log h - \log H) \times 60,384.3 \times \left(1 + \frac{t + t' - 64^\circ}{900}\right),$$

(See Art. 1304.)

$$\log \text{ of } h, 29.40 = 1.46835$$

$$\log \text{ of } H, 26.95 = 1.43056$$

$$\text{Difference} = 0.03779$$

$$1 + \frac{t + t' - 64^\circ}{900} = 1 + \frac{74 + 58 - 64}{900} = 1.0755.$$

Hence,  $Z = .03779 \times 60,384.3 \times 1.0755 = 2,454 \text{ ft.}$ , the difference in elevation between the stations.

(703) See Art. 1305.

(704) See Art. 1308.

(705) See Art. 1308.



# LAND SURVEYING.

(QUESTIONS 706-755.)

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- (706) See Art. **1309.**
- (707) See Art. **1309.**
- (708) See Art. **1310.**
- (709) See Art. **1312.**
- (710) See Art. **1313.**
- (711) See Art. **1310** and Fig. 306.
- (712) See Art. **1314** and Fig. 308.
- (713) See Art. **1314** and Fig. 309.
- (714) See Art. **1314.**
- (715) See Art. **1315** and Fig. 310.
- (716) See Art. **1317.**
- (717) See Art. **1318.**
- (718) See Art. **1319.**
- (719) See Art. **1319** and Figs. 311 and 312.
- (720) See Art. **1319.**
- (721) See Art. **1319.**

(722) See Art. 1319.

(723) See Art. 1320.

(724) See Art. 1320.

(725) See Art. 1321.

(726) The magnetic variation is determined by subtracting the present bearing from  $B$  to  $C$ , viz.,  $N\ 60^\circ\ 15'\ E$  from the original bearing, viz.,  $N\ 62^\circ\ 00'\ E$ . The difference is  $1^\circ\ 45'$  and an *east* variation; hence, to determine the present bearings of the boundaries we must *add* the *variation* to an original bearing, which was  $N\ W$  or  $S\ E$ , and *subtract* it from an original bearing, which was  $N\ E$  or  $S\ W$ . The corrected bearings will be as follows:

| Stations. | Original Bearings.          | Distances.  | Corrected Bearings.         |
|-----------|-----------------------------|-------------|-----------------------------|
| $A$       | $N\ 31\frac{1}{2}^\circ\ W$ | 10.4 chains | $N\ 33\frac{1}{4}^\circ\ W$ |
| $B$       | $N\ 62^\circ\ E$            | 9.2 chains  | $N\ 60^\circ\ 15'\ E$       |
| $C$       | $S\ 36^\circ\ E$            | 7.6 chains  | $S\ 37\frac{3}{4}^\circ\ E$ |
| $D$       | $S\ 45\frac{1}{2}^\circ\ W$ | 10.0 chains | $S\ 43\frac{3}{4}^\circ\ W$ |

(727) See Art. 1323.

(728) See Art. 1324.

(729) See Art. 1326 and Fig. 316.

(730) See Art. 1327 and Figs. 317 and 318.

(731) See Art. 1328 and Fig. 319.

(732) As the bearing of the line  $AB$  is  $N\ E$ , the end  $B$  will be east of the meridian passing through  $A$ . The depar-

ture of  $AB$  is the distance which  $B$  is east of  $A$ , or of the meridian passing through  $A$ . Now, if from  $B$  we drop a perpendicular  $BC$  upon that meridian,  $BC$  will be the departure of  $AB$ . The latitude of  $AB$  is the distance which the end  $B$  is north of the end  $A$ . The distance  $AC$ , measured on the meridian from  $A$  to the foot of the perpendicular from  $B$ , is the latitude of  $AB$ .

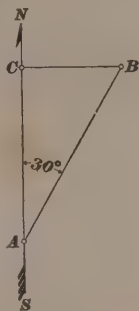


FIG. 70.

From an inspection of Fig. 70, we see that the line  $AB$ , together with its latitude  $AC$  and departure  $BC$ , form a right triangle, right angled at  $C$ , of which triangle  $BC$  is the sin and  $AC$  the cos of the bearing  $30^\circ$ . From rule 3, Art. 754, we have

$\cos A = \frac{AC}{AB}$ ; whence,  $AC = AB \cos A$ ; and from

rule 1, Art. 754,  $\sin A = \frac{BC}{AB}$ ; whence,  $BC = AB \sin$

$A$ , and we deduce the following:

Latitude = distance  $\times$  cos bearing.

Departure = distance  $\times$  sin bearing.

(733) See Art. 1329.

(734)

| Bearing.              | Distances.    | Latitudes.        | Departures.       |
|-----------------------|---------------|-------------------|-------------------|
| $23\frac{1}{4}^\circ$ | 400 ft.       | 3675              | 1579              |
|                       | 20 ft.        | 1838              | 0789              |
|                       | 3 ft.         | 2756              | 1184              |
|                       | <hr/> 423 ft. | <hr/> 388.636 ft. | <hr/> 166.974 ft. |

We divide the distance 423 ft. into three parts, viz., 400 ft., 20 ft., and 3 ft. If now we find the latitude and departure for 4 ft. and multiply them by 100, we shall obtain the latitude and departure for 400 ft. The latitude of 4 ft. is 3.675 ft., and the departure 1.579 ft. We place these figures under their proper headings as whole numbers. The latitude and departure of 2 ft. are 1.838 and 0.789, respectively, which we place as whole numbers under their proper

headings, but removed one place to the right of the figures above them, as they are the latitude and departure of tens of feet. The latitude and departure of 3 ft. are 2.756 ft. and 1.184 ft., respectively, and we place them under their proper headings, but removed one place to the right as they are for units of feet. We now add up the partial latitudes and departures, and from the right of each sum we point off three decimal places, the same number as given in the traverse table, giving us for the required latitude 388.636 ft., and for the required departure 166.974 ft.

**(735)**

| Bearing. | Distances. | Latitudes.  | Departures. |
|----------|------------|-------------|-------------|
| 40°      | 200 ft.    | 1532        | 1286        |
|          | 20 ft.     | 1532        | 1286        |
|          | 5 ft.      | 3830        | 3214        |
|          | 225 ft.    | 172.350 ft. | 144.674 ft. |

For the given bearing of 40° and distance of 225 ft., the latitude is 172.35 ft., and the *departure* 144.674 ft.

The complement of the given bearing is the difference between 90° and 40°, which is 50°. With this complement as the bearing, we have

| Bearing. | Distances. | Latitudes.  | Departures.  |
|----------|------------|-------------|--------------|
| 50°      | 200 ft.    | 1286        | 1532         |
|          | 20 ft.     | 1286        | 1532         |
|          | 5 ft.      | 3214        | 3830         |
|          | 225 ft.    | 144.674 ft. | 172.350 ft., |

in which the latitude and departure are exactly the reverse of those when the line had a bearing of 40°, the complement of 50°.

**(736)** See Art. 1330.

**(737)** We rule 11 columns, headed as below. The latitudes and departures for the several courses we calculate by traverse tables; placing the *north* latitudes, which are +, in the column headed N +, and the *south* latitudes, which are -, in the column headed S -; the *east* departures, which are



+, in the column headed E +, and the *west* departures, which are —, in the column headed W —. These several columns we add, placing their sums at the foot of the columns. The sum of the distances is 37.20 chains; the sum of the north latitudes 13.19 chains, and of the south latitudes 13.16 chains. The difference is .03 chain, or 3 links. The sum of the east departures is 12.60 chains, and the sum of the west departures is 12.56 chains. The difference is .04 chain, or 4 links.

This difference indicates an error in either the bearings or measurements of the line or both. For had the work been correct, the sums of the north and south latitudes would have been equal. (See Art. 1330.) The corrections for latitudes and departures are made as shown in the following proportions, the object of such correction being to make the sums of the north and south latitudes and of the east and west longitudes equal, and is called balancing the survey. (See Art. 1331.)

| Sta-<br>tions. | Bearings. | Distances | Latitudes. |       | De-<br>partures. |       | Corrected<br>Latitudes. |       | Corrected<br>De-<br>partures. |       |
|----------------|-----------|-----------|------------|-------|------------------|-------|-------------------------|-------|-------------------------------|-------|
|                |           |           | N +        | S     | E +              | W -   | N +                     | S     | E +                           | W -   |
| 1              | N 31½° W  | 10.40 ch. | 8.87       |       |                  | 5.43  | 8.86                    |       |                               | 5.44  |
| 2              | N 62° E   | 9.20 ch.  | 4.32       |       | 8.13             |       | 4.31                    |       | 8.12                          |       |
| 3              | S 36° E   | 7.60 ch.  |            | 6.15  | 4.47             |       |                         | 6.15  | 4.46                          |       |
| 4              | S 45½° W  | 10.00 ch. |            | 7.01  |                  | 7.13  |                         | 7.02  |                               | 7.14  |
|                |           | 37.20     | 13.19      | 13.16 | 12.60            | 12.56 | 13.17                   | 13.17 | 12.58                         | 12.58 |

Difference between N and S latitudes = .03 chain = 3 links.

Difference between E and W departures = .04 chain = 4 links.

Corrections for Latitudes.

37.20 : 10.40 :: 3 : 1 link

37.20 : 9.20 :: 3 : 1 link

37.20 : 7.60 :: 3 : 0 link

37.20 : 10.00 :: 3 : 1 link

Corrections for Departures.

37.20 : 10.40 :: 4 : 1 link

37.20 : 9.20 :: 4 : 1 link

37.20 : 7.60 :: 4 : 1 link

37.20 : 10.00 :: 4 : 1 link

Taking the first proportion, we have 37.20 ch., the sum of all the distances : 10.40 ch., the first distance :: 3 links, the total error : 1 link, the correction for the first distance. The latitude of the first course, viz., 8.87 ch., is north, and as the sum of the north latitudes is the greater, we *subtract* the correction leaving 8.86 chains. The correction for the latitudes of the second course is 1 link, and is likewise subtracted. The correction for the third course is less than 1 link, and is ignored. The correction for the latitude of the fourth course is 1 link, and as the sum of the south latitudes is less than the north latitudes we *add* the correction. We place the corrected latitudes in the eighth and ninth columns. In a similar manner we correct the departures, as shown in the above proportions, placing the corrected departures in the tenth and eleventh columns.

(738) We rule three columns as shown below, the first column for stations, the second for total latitudes from Sta. 2, and the third for total departures from Sta. 2. Station 2 being a point only, its latitude and departure are 0. The latitude of the second course, i. e., from Sta. 2 to Sta. 3, is + 4.31 chains, and the departure + 8.12 chains. These distances we place opposite Sta. 3, in their proper columns. The latitude of the third course, i. e., from Sta. 3 to Sta. 4, is - 6.15 chains, and the departure + 4.46 chains. Therefore, the total latitude from Sta. 2 is the sum of + 4.31 and - 6.15, which is - 1.84 chains. The total departure from Sta. 2 is the sum of + 8.12 and + 4.46, which is + 12.58 chains. These totals we place opposite Sta. 4 in their proper columns. The latitude of the fourth course, i. e., from Sta. 4 to Sta. 1, is - 7.02 chains, and the departure - 7.14 chains. These quantities we add with their proper signs to those previously obtained, which give us the total latitudes and departures from the initial Sta. 2, and we have, for the total latitude of Sta. 1, the sum of - 1.84 and - 7.02, which is - 8.86 chains, and for the total departure the sum of + 12.58 and - 7.14, which is + 5.44 chains. The latitude of the first course, i. e., from Sta. 1 to Sta. 2,

is  $+8.86$  chains, and the departure  $-5.44$  chains. These quantities we add with their proper signs to those already obtained, giving us the total latitudes and departures from Sta. 2, and we have for the total latitude of Sta. 2 the sum of  $-8.86$  and  $+8.86$ , which is 0; and for the total departure, the sum of  $+5.44$  and  $-5.44$ , which is 0. The latitude and departure of Sta. 2 coming out equal to 0, proves the work to be correct. (See Art. 1332.) A plat of this survey made from total latitudes and departures from Sta. 2 is given in Fig. 71.

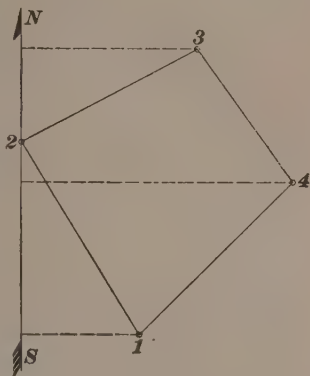


FIG. 71.

Through Sta. 2 draw a meridian  $N\ S$ . Lay off on this meridian above Sta. 2 the total latitude at Sta. 3, viz.,  $+4.31$  chains, a north latitude, and at its extremity erect a right perpendicular to the meridian, and upon this perpendicular scale off the total departure of Sta. 3, viz.,  $+8.12$  chains, an east departure locating Sta. 3. A line joining Stations 2 and 3 will have the direction and length of the second course. For Sta. 4 we have a total latitude of  $-1.84$  chains, a south latitude which we scale off on the meridian below Sta. 2. The total departure of this station is  $+12.58$  chains, which we lay off on a right perpendicular to the meridian, locating Sta. 4. A line joining Stations 3 and 4 gives the direction and length of the third course.

| Stations. | Total Latitudes<br>from Station 2. | Total<br>Departures<br>from Station 2. |
|-----------|------------------------------------|----------------------------------------|
| 2         | 0.00 ch.                           | 0.00 ch.                               |
| 3         | $+4.31$ ch.                        | $+8.12$ ch.                            |
| 4         | $-1.84$ ch.                        | $+12.58$ ch.                           |
| 1         | $-8.86$ ch.                        | $+5.44$ ch.                            |
| 2         | 0.00 ch.                           | 0.00 ch.                               |

The total latitude of sta. 1 is  $- 5.31$  chains, a south latitude, which we scale off on the meridian below Sta. 2. The total departure of Sta. 1 is  $+ 4.44$  chains, an east departure, which we scale off to the right perpendicular to the meridian, leaving Sta. 1. A line joining Stations 4 and 1 will have the direction and length of the fourth course. The total latitude and departure of Sta. 2 being 0, a line joining Sta. 1 with Sta. 2 will have the direction and length of the first course, and the resulting figure 2, 3, 4, 1 is the required plat of the survey.

(739) See Art. 1334.

(740) See Art. 1335.

(741) See Art. 1336 and Fig. 323.

(742) See Art. 1336.

(743) The signs of the latitude always determine the character of the products, north or  $+$  latitudes giving north products and south or  $-$  latitudes giving south products. See Examples 746 and 747.

(744) See Art. 1338.

(745) Rule twelve columns with headings as shown in the following diagram, calculate the latitudes and departures, placing them in proper order. Balance them, writing the corrected latitudes directly above the original latitudes, which are crossed out. Calculate the double longitudes from Sta. 2 by rule given in Art. 1335, and place them with their corresponding stations as shown in columns 11 and 12. Place the double longitudes in regular order in column 8. Multiply the double longitude of each course by the corrected latitude of that course, placing the products in column 9 or 10, according as the products are north or south. Add the columns of double areas, subtracting the less from the greater and divide the remainder by 2. In this example the area is given in square chains, which we reduce to acres, roods, and poles as follows: Divide the sq. chains by 10, reducing to acres. Multiply the decimal part successively by 4 and 40, reducing to roods and poles.

| Sta-<br>tions. | Bearings. | Distances. | Latitudes.       |                  | Departures. |      | Double<br>Longi-<br>tudes. | Double Areas.        |         | Sta-<br>tions. | D. L.         |
|----------------|-----------|------------|------------------|------------------|-------------|------|----------------------------|----------------------|---------|----------------|---------------|
|                |           |            | N +              | S -              | E +         | W -  |                            | N +                  | S -     |                |               |
| 1              | S 21° W   | 12.41 ch.  |                  | 11.62            |             | 4.44 | + 4.44                     |                      | 51.5928 | 2              | + 5.82 D. L.  |
| 2              | N 83½° E  | 5.86 ch.   | 0.69             | <del>11.59</del> | 5.82        |      | + 5.82                     | 4.0158               |         |                | + 5.82        |
| 3              | N 12° E   | 8.25 ch.   | 8.05             |                  | 1.72        |      | + 13.36                    | 107.5480             |         | 3              | + 13.36 D. L. |
| 4              | N 47° W   | 4.24 ch.   | 2.88             |                  |             | 3.10 | + 11.98                    | 34.5024              |         |                | + 1.72        |
| 30.76 ch.      |           |            | <del>11.63</del> | <del>11.59</del> | 7.54        | 7.54 |                            | 146.0662             |         | 4              | + 11.98 D. L. |
|                |           |            | 11.62            | 11.62            | 7.54        | 7.54 |                            | 51.5928              |         |                | - 3.10        |
|                |           |            |                  |                  |             |      |                            | 2 ) 94.4754          |         |                | - 4.44        |
|                |           |            |                  |                  |             |      |                            | 10 ) 47.2367 sq. ch. |         | 1              | + 4.44 D. L.  |
|                |           |            |                  |                  |             |      |                            | 4.72367              |         |                |               |
|                |           |            |                  |                  |             |      |                            | 4                    |         |                |               |
|                |           |            |                  |                  |             |      |                            | 2.89468              |         |                |               |
|                |           |            |                  |                  |             |      |                            | 40                   |         |                |               |
|                |           |            |                  |                  |             |      |                            | 35.78720             |         |                |               |

Content = 4 A. 2 R. 35.8 P.

In this example, the meridian from which we calculate the double longitudes passes through Sta. 2, the extreme westerly one.

(746)

| Sta-<br>tions.                                                                                                                        | Bearings. | Distances. | Latitudes.   |                | Departures. |                                                        | Double<br>Longi-<br>tudes. | Double Areas. |          | Sta-<br>tions. | D. L.                              |
|---------------------------------------------------------------------------------------------------------------------------------------|-----------|------------|--------------|----------------|-------------|--------------------------------------------------------|----------------------------|---------------|----------|----------------|------------------------------------|
|                                                                                                                                       |           |            | N +          | S -            | E +         | W -                                                    |                            | N +           | S -      |                |                                    |
| 1                                                                                                                                     | S 21½° W  | 17.62 ch.  |              | 16.41<br>16.42 |             | 6.40<br>6.38<br>5.60                                   | - 6.40                     |               | 105.0240 | 1              | - 6.40 D. L.<br>- 6.40<br>- 5.60   |
| 2                                                                                                                                     | S 34° W   | 10.00 ch.  |              | 8.29           |             | 11.76<br>11.73                                         | - 18.40                    |               | 152.5360 | 2              | - 18.40 D. L.<br>- 5.60<br>- 11.76 |
| 3                                                                                                                                     | N 56° W   | 14.15 ch.  | 7.92<br>7.91 |                |             | 5.45<br>5.46<br>2.12<br>2.75<br>1.40<br>12.04<br>12.06 | - 35.76                    | 283.2192      |          | 3              | - 35.76 D. L.<br>- 11.76<br>+ 5.45 |
| 4                                                                                                                                     | N 34° E   | 9.76 ch.   | 8.09         |                |             |                                                        | - 42.07                    | 340.3463      |          | 4              | - 42.07 D. L.<br>+ 5.45<br>+ 2.12  |
| 5                                                                                                                                     | N 67° E   | 2.30 ch.   | 0.90         |                |             |                                                        | - 34.50                    | 31.0500       |          | 5              | - 34.50 D. L.<br>+ 2.12<br>+ 2.75  |
| 6                                                                                                                                     | N 23° E   | 7.03 ch.   | 6.47         |                |             |                                                        | - 29.63                    | 191.7061      |          | 6              | - 29.63 D. L.<br>+ 2.75<br>+ 1.40  |
| 7                                                                                                                                     | N 18½° E  | 4.43 ch.   | 4.20         |                |             |                                                        | - 25.48                    | 107.0160      |          | 7              | - 25.48 D. L.<br>+ 1.40<br>+ 12.04 |
| 8                                                                                                                                     | S 76½° E  | 12.41 ch.  |              | 2.88<br>2.89   |             |                                                        | - 12.04                    | 34.6752       |          | 8              | - 12.04 D. L.                      |
| 77.70 ch. 27.57 27.60 23.79 23.70                                                                                                     |           |            |              |                |             |                                                        |                            |               |          |                |                                    |
| 27.58 27.58 23.76 23.76                                                                                                               |           |            |              |                |             |                                                        |                            |               |          |                |                                    |
| Content = 33 A. 0 R. 8.8 P.                                                                                                           |           |            |              |                |             |                                                        |                            |               |          |                |                                    |
| 953.3376 292.2352<br>2)661.1024<br>10)330.5512 sq. ch.<br>33.05512<br>4<br>22048<br>40<br>8.81920                                     |           |            |              |                |             |                                                        |                            |               |          |                |                                    |
| In this example, the meridian from which we calculate the<br>double longitudes passes through Sta. 1, the extreme east-<br>early one. |           |            |              |                |             |                                                        |                            |               |          |                |                                    |



| Sta-<br>tions | Bearings.              | Distances,<br>Chains. | Latitudes. |      | Departures. |      | Double Longi-<br>tudes. |  | Double Areas. |             | Stations. | D. L.       |
|---------------|------------------------|-----------------------|------------|------|-------------|------|-------------------------|--|---------------|-------------|-----------|-------------|
|               |                        |                       | N +        | S -  | E +         | W -  |                         |  | N +           | S -         |           |             |
| 1             | N 18 $\frac{3}{4}$ ° E | 1.93                  | 1.83       |      | 0.62        |      | + 1.10                  |  | 2.0130        |             | 4         | + 0.91 D.L. |
| 2             | N 9° W                 | 1.29                  | 1.27       |      |             | 0.20 | + 1.52                  |  | 1.9304        |             |           | + 0.91      |
| 3             | N 14° W                | 2.71                  | 2.63       |      |             | 0.66 | + 0.66                  |  | 1.7358        |             | 5         | + 1.19      |
| 4             | N 74° E                | 0.95                  | 0.26       |      | 0.91        |      | + 0.91                  |  | 0.2366        |             |           | + 3.01 D.L. |
| 5             | S 48 $\frac{1}{2}$ ° E | 1.59                  |            | 1.05 | 1.19        |      | + 3.01                  |  |               | 3.1605      | 6         | + 4.48 D.L. |
| 6             | S 14 $\frac{1}{2}$ ° E | 1.14                  |            | 1.10 | 0.28        |      | + 4.48                  |  |               | 4.9280      |           | + 0.28      |
| 7             | S 19 $\frac{1}{2}$ ° E | 2.15                  |            | 2.03 | 0.72        |      | + 5.48                  |  |               | 11.1244     |           | + 0.72      |
| 8             | S 23 $\frac{1}{2}$ ° W | 1.22                  |            | 1.12 |             | 0.49 | + 5.71                  |  |               | 6.3952      | 7         | + 5.48 D.L. |
| 9             | S 5° W                 | 1.40                  |            | 1.39 |             | 0.12 | + 5.10                  |  |               | 7.0890      |           | + 0.72      |
| 10            | S 30° W                | 1.02                  |            | 0.88 |             | 0.51 | + 4.47                  |  |               | 3.9336      |           | - 0.49      |
| 11            | S 81 $\frac{1}{2}$ ° W | 0.69                  |            | 0.10 |             | 0.68 | + 3.28                  |  |               | 0.3280      | 8         | + 5.71 D.L. |
| 12            | N 32 $\frac{1}{2}$ ° W | 1.98                  | 1.67       |      |             | 1.06 | + 1.54                  |  | 2.5718        |             |           | - 0.49      |
|               |                        |                       | 7.66       | 7.67 | 3.72        | 3.72 |                         |  | 8.4876        | 36.9587     | 9         | + 5.10 D.L. |
|               |                        |                       |            |      |             |      |                         |  | 8.4876        |             |           | - 0.12      |
|               |                        |                       |            |      |             |      |                         |  |               | - 0.51      |           | - 0.51      |
|               |                        |                       |            |      |             |      |                         |  |               | + 4.47 D.L. | 10        | + 4.47 D.L. |
|               |                        |                       |            |      |             |      |                         |  |               | - 0.51      |           | - 0.51      |
|               |                        |                       |            |      |             |      |                         |  |               | - 0.68      |           | - 0.68      |
|               |                        |                       |            |      |             |      |                         |  |               | + 3.28 D.L. | 11        | + 3.28 D.L. |
|               |                        |                       |            |      |             |      |                         |  |               | - 0.68      |           | - 0.68      |
|               |                        |                       |            |      |             |      |                         |  |               | - 1.06      |           | - 1.06      |
|               |                        |                       |            |      |             |      |                         |  |               | + 1.54 D.L. | 12        | + 1.54 D.L. |
|               |                        |                       |            |      |             |      |                         |  |               | - 1.06      |           | - 1.06      |
|               |                        |                       |            |      |             |      |                         |  |               | + 0.62      |           | + 0.62      |
|               |                        |                       |            |      |             |      |                         |  |               | + 1.10 D.L. | 1         | + 1.10 D.L. |
|               |                        |                       |            |      |             |      |                         |  |               | + 0.62      |           | + 0.62      |
|               |                        |                       |            |      |             |      |                         |  |               | - 0.20      |           | - 0.20      |
|               |                        |                       |            |      |             |      |                         |  |               | + 1.52 D.L. | 2         | + 1.52 D.L. |
|               |                        |                       |            |      |             |      |                         |  |               | - 0.20      |           | - 0.20      |
|               |                        |                       |            |      |             |      |                         |  |               | - 0.66      |           | - 0.66      |
|               |                        |                       |            |      |             |      |                         |  |               | + 0.66 D.L. | 3         | + 0.66 D.L. |

Content, 1 A. 1 R. 27 $\frac{1}{4}$  P.

Sq. chains 10)14.2355

2)28.4711

1.42355

4

1.69420

40

27.76800

In this example, the meridian from which we calculate the double longitudes passes through Sta. 4, the extreme westerly one.

- (748) See Art. **1339**.
- (749) See Art. **1340** and Fig. 326.
- (750) See Art. **1341** and Fig. 327.
- (751) See Art. **1341**.
- (752) See Art. **1342**.
- (753) See Art. **1343** and Fig. 327.
- (754) See Art. **1344**.
- (755) See Art. **1343**.

# RAILROAD LOCATION.

(QUESTIONS 756-812.)

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(756) See Art. 1392.

(757) See Art. 1393.

(758) See Art. 1393.

(759) See Art. 1394.

(760) This question is asked in order to elicit *individual* judgment.

(761) See Art. 1395.

(762) See Art. 1396.

(763) See Art. 1397.

(764) See Art. 1398.

(765) See Art. 1399.

(766) See Art. 1399.

(767) See Art. 1400.

(768) See Art. 1401.

(769) See Art. 1402.

(770) See Art. 1403.

(771) See Art. 1404.

(772) See Art. 1405.

(773) See Arts. 1406 and 1407.

(774) See Art. 1408.

(775) See Art. 1409.

(776) See Art. 1409.

(777) See Arts. 1410 and 1412.

(778) See Art. 1413.

(779) See Art. 1414.

(780) See Art. 1415.

(781) See Art. 1416.

(782) See Art. 1416.

(783) See Art. 1417.

(784) See Art. 1418.

(785) See Art. 1419.

(786) See Art. 1420.

(787) This is an example under Problem I, Art. 1422. The distance which the P. C. must be moved backwards is equal to 26 ft., the distance between the parallel tangents, divided by the sin of  $32^{\circ} 30'$ , the intersection angle of the curve.  $\sin 32^{\circ} 30' = .5373$ ;  $\frac{26 \text{ ft.}}{.5373} = 48.39 \text{ ft.}$

(788) This question also comes under Problem I, Art. 1422. We must move the P. C. forwards a distance equal to 13.4 divided by  $\sin 41^{\circ} 20'$ .  $\sin 41^{\circ} 20' = .66044$ .  $\frac{13.4 \text{ ft.}}{.66044} = 20.29 \text{ ft.}$

(789) This question comes under Problem II, Case 2, Art. 1424. As we must move the P. C. C. backwards, we must increase the angle of the second curve. This will diminish the cos of the angle of the second curve, and  $D$ , the distance between the tangents, will be *negative*. Accordingly, we use formula 100,  $\cos y = \frac{(R - r) \cos x - D}{R - r}$  (see Art. 1424), in which  $x = 34^{\circ} 20'$ , the angle of the

second curve;  $R = 955.37$  ft., the radius of the  $6^\circ$  curve, and  $r = 637.27$  ft., the radius of  $9^\circ$  curve, and  $D = 26.4$  ft. Substituting these values in the foregoing formula, we have

$$\cos y = \frac{(955.37 - 637.27) \times .82577 - 26.4}{955.37 - 637.27} = 0.7428, \text{ the cos of } 42^\circ 02'.$$

As the given angle of the second curve is  $34^\circ 20'$ , and the required angle  $42^\circ 02'$ , the difference, viz.,  $7^\circ 42'$ , we must deduct from the first curve. The distance which we must retreat on the first curve we determine by dividing the angle  $7^\circ 42'$  by 6, the degree of the first curve. The quotient will be the required distance in stations. Reducing  $7^\circ 42'$  to the decimal of a degree, we have  $7.7^\circ$ .  $\frac{7.7}{6} = 1.2833$  stations  $= 128.33$  ft.

**(790)** This question comes under Problem II, Case 1, Art. **1423**, but the tangent falls within instead of without the required tangent. Consequently, we must advance the P. C. C., which will diminish the angle of the second curve and, consequently, increase its cos.  $D$ , the distance between the given tangents, will, therefore, be *positive*, giving us formula **99**, viz.,  $\cos y = \frac{(R - r) \cos x + D}{R - r}$  (see Art. **1423**), in which  $x = 36^\circ 40'$ , the angle of the second curve;  $R = 1,910.08$  ft., the radius of a  $3^\circ$  curve;  $r = 819.02$  ft., the radius of a  $7^\circ$  curve, and  $D = 32.4$  ft., the distance between the tangents. Substituting these values in the given formula, we have

$$\cos y = \frac{(1,910.08 - 819.02) \times .80212 + 32.4}{1,910.08 - 819.02} = .83181, \text{ the cos of } 33^\circ 43'.$$

The given angle of the second curve is  $36^\circ 40'$ , and the required angle is  $33^\circ 43'$ . The difference,  $2^\circ 57'$ , we must deduct from the second curve and add it to the first curve. To determine the number of feet which we must add to the first curve, we divide the angle  $2^\circ 57'$  by 3, the

degree of the first curve. The quotient will be the distance in full stations. Reducing  $2^{\circ} 57'$  to decimal form of a degree, we have  $2.95^{\circ}$ .  $\frac{2.95}{3} = 0.9833$  station = 98.33 ft., the distance which the P. C. C. must be advanced.

(791) This question comes under Problem II, Case 1. (See Art. 1423.) In this case we must increase the angle of the second curve, and, consequently, diminish the length of the cos. Hence,  $D$ , the distance between the given tangents, will be negative, and the formula will read

$$\cos y = \frac{(R - r) \cos x - D}{R - r} \quad (\text{see formula 100, Art. 1423}),$$

in which  $x = 37^{\circ} 10'$ , the angle of the second curve;  $R = 1,432.69$  ft., the radius of a  $4^{\circ}$  curve;  $r = 955.37$  ft., the radius of a  $6^{\circ}$  curve, and  $D = 56$  ft., the distance between the given tangents. Substituting these values in the given formula, we have

$$\cos y = \frac{(1,432.69 - 955.37) \times .79688 - 56}{1,432.69 - 955.37} = .67956 = \cos 47^{\circ} 11'.$$

The given angle of the second curve is  $37^{\circ} 10'$ , and the required angle,  $47^{\circ} 11'$ . The difference, viz.,  $10^{\circ} 01'$ , we must add to the second curve and deduct from the first curve. The distance backwards which we must move the P. C. C. we obtain by dividing the angle  $10^{\circ} 01'$  by 4, the degree of the first curve. The quotient gives the distance in full stations.  $10^{\circ} 01'$  in decimal form is  $10.016^{\circ}$ .  $\frac{10.016}{4} = 2.504$  stations = 250.4 ft.

(792) This question comes under Problem II, Case 2, Art. 1424. Here we must reduce the angle of the second curve, and, consequently, increase the length of its cos. Hence,  $D$ , the distance between the given tangents, is positive, and our formula is

$$\cos y = \frac{(R - r) \cos x + D}{R - r},$$

in which  $x = 28^\circ 40'$ , the given angle of the second curve;  $R = 1,910.08$  ft., the radius of a  $2^\circ$  curve;  $r = 716.78$  ft., the radius of an  $8^\circ$  curve, and  $D = 25.4$  ft., the distance between the given tangents. Substituting these values in the above formula, we have

$$\cos y = \frac{(1,910.08 - 716.78) \times .87743 + 25.4}{1,910.08 - 716.78} = .89872 = \cos 26^\circ 00'.$$

The given angle of the second curve is  $28^\circ 40'$ , and the required angle is  $26^\circ 00'$ . The difference,  $2^\circ 40'$ , we must deduct from the second curve and add to the first, i. e., we must advance the P. C. C. The number of feet which we advance the P. C. C. we determine by dividing the angle  $2^\circ 40'$  by 8, the degree of the first curve; the quotient gives the distance in stations. Reducing  $2^\circ 40'$  to the decimal of a degree, we have  $2.6667^\circ$ .  $\frac{2.6667}{8} = .3333$  station = 33.33 ft.

**(793)** This question is also under Problem II, Case 2. (See Art. **1424**.) Here we increase the angle of the second curve, and, consequently, diminish the cos, and  $D$  the distance between the tangents is negative. We use formula **100**,  $\cos y = \frac{(R - r) \cos x - D}{R - r}$ , in which  $x = 36^\circ 15'$ ,  $R = 1,432.69$  ft.,  $r = 637.27$  ft., and  $D = 33$  ft. Substituting these values in the given formula, we have

$$\cos y = \frac{(1,432.69 - 637.27) \times .80644 - 33}{1,432.69 - 637.27} = .76495 \cos 40^\circ 06'.$$

The given angle of the second curve is  $36^\circ 15'$  and the required angle  $40^\circ 06'$ . The difference, viz.,  $3^\circ 51'$ , we add to the second curve and deduct from the first. We must, therefore, place the P. C. C. back of the given P. C. C., and this distance we find by dividing the angle  $3^\circ 51'$  by 9, the degree of the first curve. Reducing  $3^\circ 51'$  to decimal form, we have  $3.85^\circ$ .  $\frac{3.85}{9} = .4278$  station = 42.78 ft.

**(794)** This question comes under Problem III, Art. **1425**. The radius of a  $7^\circ$  curve is 819.02 ft. The radius



of the parallel curve will be  $819.02 - 100 = 719.02$  ft. The chords on the  $7^\circ$  curve are each 100 ft., and we obtain the length of the parallel chords from the following proportion:

$$819.02 : 719.02 :: 100 \text{ ft.} : \text{the required chord.}$$

$$\text{Whence, we have required chord} = \frac{719.02 \times 100}{819.02} = 87.79 \text{ ft.}$$

**(795)** This question comes under Problem IV, Art. **1426**.

$$\frac{34^\circ 20'}{2} = 17^\circ 10'; \quad \frac{41^\circ 30'}{2} = 20^\circ 45'.$$

The distance between intersection points is 1,011 ft. From Art. **1426**, we have

$$(\tan 17^\circ 10' + \tan 20^\circ 45') : \tan 17^\circ 10' :: 1,011 : \text{the tangent distance of the first curve.}$$

$$\text{Whence, } (.30891 + .37887) : .30891 :: 1,011 \text{ ft.} : \text{the tangent distance.}$$

$$\text{Whence, tangent distance of the first curve} = \frac{312.308}{.68778} = 454.08 \text{ ft.}$$

Substituting known values in formula **91**,  $T = R \tan \frac{1}{2} I$  (see Art. **1251**), we have  $454.08 = R \times .30891$ ; whence,  $R = \frac{454.08}{.30891} = 1,469.94$  ft. Dividing 5,730 ft., the radius of a  $1^\circ$  curve, by 1,469.94, the length of the required radius, the quotient 3.899 is the degree of the required curve. Reducing the decimal to minutes, we have the degree of the required curve =  $3^\circ 53.9'$ .

**(796)** This question also comes under Problem IV, Art. **1426**. We have

$$\frac{20^\circ 14'}{2} = 10^\circ 07'; \quad \frac{41^\circ 08'}{2} = 20^\circ 34'.$$

The distance between intersection points is 816 ft. From Art. **1426**, we have

$$(\tan 10^\circ 07' + \tan 20^\circ 34') : \tan 10^\circ 07' :: 816 \text{ ft.} : \text{the tangent distance of the first curve.}$$

Whence, we have  $(.17843 + .37521, : .17843 :: 816 : \text{tangent distance})$ .

$$\text{Whence, tangent distance} = \frac{145.5989}{.55364} = 262.985 \text{ ft.}$$

Substituting known values in formula **91**,  $T = R \tan \frac{1}{2} I$  (see Art. **1251**), we have  $262.985 = R \times .17843$ ; whence,  
 $R = \frac{262.985}{.17843} = 1,473.88 \text{ ft.} = \text{the radius of a } 3^\circ 53.3' \text{ curve.}$

**(797)** This question comes under Problem V, Art. **1427**. The required radius is equal to 470 ft. divided by  $(\tan \frac{1}{2} 28^\circ 40' + \tan \frac{1}{2} 30^\circ 16')$ .  $\frac{28^\circ 40'}{2} = 14^\circ 20'$ ;  $\tan 14^\circ 20' = .25552$ .  $\frac{30^\circ 16'}{2} = 15^\circ 08'$ ;  $\tan 15^\circ 08' = .27044$ . The sum of these tangents is .52596, and we have  $R = \frac{470 \text{ ft.}}{.52596} = 893.64 \text{ ft.}$  Dividing 5,730 ft., the radius of a  $1^\circ$  curve, by the radius 893.64 ft., the quotient is the degree of the required curve.  $\frac{5,730}{893.64} = 6.412^\circ = 6^\circ 24.7' \text{ curve.}$

**(798)** This question also comes under Problem V, Art. **1427**. The required radius  $R = \frac{516 \text{ ft.}}{\tan \frac{1}{2} 32^\circ 50' + \tan \frac{1}{2} 41^\circ 20'}$ .  $\frac{32^\circ 50'}{2} = 16^\circ 25'$ .  $\tan 16^\circ 25' = .29463$ .  $\frac{41^\circ 20'}{2} = 20^\circ 40'$ .  $\tan 20^\circ 40' = .3772$ .  $.29463 + .37720 = .67183$ . Substituting this value in the above equation, we have  $R = \frac{516}{.67183} = 768.05 \text{ ft., the radius of a } 7^\circ 27.6' \text{ curve.}$

**(799)** This question comes under Problem VII, Art. **1429**. The required distance across the stream  $= \frac{7.3 \times 100}{1.745} = 418.3 \text{ ft.}$

**(800)** See Art. **1433**.

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(801) See Art. 1434.

(802) See Art. 1435.

(803) The usual compensations for curvature are from .03 ft. to .05 ft. per degree.

(804) As the elevation of grade at Sta. 20 is 118.5 ft., and that at Sta. 40 is 142.5 ft., the total actual rise between those stations is the difference between 142.5 and 118.5, which is 24 ft. Hence, the average grade between those points is  $\frac{24}{20} = 1.2$  ft. per station. As the resistance owing to the curvature is equivalent to an increase in grade of .03 ft. per each degree, the total increase in grade owing to curvature is equal to .03 ft. multiplied by 78, the total number of degrees of curvature between Sta. 20 and Sta. 40.  $78 \times .03 = 2.34$  ft. This amount we add to 24 ft., the total actual rise between the given stations, making a total *theoretical* rise of 26.34 ft. Dividing 26.34 by 20, we obtain for the tangents on this portion of the line an ascending grade of 1.317 ft. per station. Hence, the grade between Sta. 20 and Sta. 24 + 50 is + 1.317 ft. per station. The distance between Sta. 20 and Sta. 24 + 50 is 450 ft. = 4.5 stations, and the total rise between these stations is 1.317 ft.  $\times$  4.5 = 5.9265 ft., which we add to 118.5 ft., the elevation of grade at Sta. 20, giving 124.4265 ft. for the elevation of grade at Sta. 24 + 50. The first curve is  $10^\circ$ , which is equivalent to a grade of .03 ft.  $\times$  10 = 0.3 ft. per station, which we subtract from 1.317, the grade for tangents. The difference, 1.017, is the grade on the  $10^\circ$  curve, the length of which is 420 ft. = 4.2 stations. Multiplying 1.017 ft., the grade on the 10 curve, by 4.2, we have 4.2714 ft. as the total rise on that curve; the P. T. of which is Sta. 28 + 70. Adding 4.2714 ft. to 124.4265 ft., we have 128.6979 ft., the elevation of grade at Sta. 28 + 70. The line between Sta. 28 + 70 and Sta. 31 + 80 being tangent, has a grade of 1.317 ft. The distance between these stations is 310 ft. = 3.1 stations, and the total rise between the stations is  $1.317 \times 3.1 =$

4.0827 ft., which we add to 128.6979 ft., the elevation of grade at Sta. 28 + 70, giving 132.7806 ft. for the elevation of grade at Sta. 31 + 80. Here we commence an 8° curve for 450 ft. = 4.5 stations. The compensation in grade for an 8° curve is .03 ft.  $\times$  8 = 0.24 ft. per station. Hence, the grade for that curve is 1.317 ft. - 0.24 ft. = + 1.077 ft. per station, and the total rise on the 8° curve is 1.077 ft.  $\times$  4.5 = 4.8465 ft., which we add to 132.7806, the elevation of grade at Sta. 31 + 80, giving 137.6271 ft. for the elevation of grade at Sta. 36 + 30, the P. T. of the 8° curve. The line between Sta. 36 + 30 and Sta. 40 is a tangent, and has a grade of + 1.317 ft. per station. The distance between these stations is 370 ft. = 3.7 stations, and the total rise is 1.317  $\times$  3.7 = 4.8729 ft., which, added to 137.6271 ft., the elevation of grade at Sta. 36 + 30, gives 142.5 ft. for the elevation of grade at Sta. 40.

(805) See Art. 1439.

(806) In this question,  $g = +1.0$  ft.,  $g' = -0.8$  ft. and  $n = 3$ . Substituting these values in formula 101,

$$a = \frac{g - g'}{4n} \text{ (see Art. 1440), we have } a = \frac{1.0 - (-0.8)}{12} =$$

$$\frac{1.8}{12} = 0.15 \text{ ft. The successive grades or additions for the}$$

6 stations of the vertical curve are the following:  $g - a$ ,  $g - 3a$ ,  $g - 5a$ ,  $g - 7a$ ,  $g - 9a$ ,  $g - 11a$ . Substituting known values of  $g$  and  $a$ , we have for the successive grades:

| Stations. | Heights of Curve<br>Above Starting<br>Point.     |                          |
|-----------|--------------------------------------------------|--------------------------|
| 1.        | $g - a = 1.0 \text{ ft.} - 0.15 \text{ ft.} =$   | 0.85 ft. .... 0.85 ft.   |
| 2.        | $g - 3a = 1.0 \text{ ft.} - 0.45 \text{ ft.} =$  | 0.55 ft. .... 1.40 ft.   |
| 3.        | $g - 5a = 1.0 \text{ ft.} - 0.75 \text{ ft.} =$  | 0.25 ft. .... 1.65 ft.   |
| 4.        | $g - 7a = 1.0 \text{ ft.} - 1.05 \text{ ft.} =$  | - 0.05 ft. .... 1.60 ft. |
| 5.        | $g - 9a = 1.0 \text{ ft.} - 1.35 \text{ ft.} =$  | - 0.35 ft. .... 1.25 ft. |
| 6.        | $g - 11a = 1.0 \text{ ft.} - 1.65 \text{ ft.} =$ | - 0.65 ft. .... 0.60 ft. |

As the elevation of the grade at the starting point of the

curve (which we will call Sta. 0) is 110 ft., the elevations of the grades for all the stations of the curve are the following:

| Stations. | Elevation of Grade. |
|-----------|---------------------|
| 0.....    | 110.00              |
| 1.....    | 110.85              |
| 2.....    | 111.40              |
| 3.....    | 111.65              |
| 4.....    | 111.60              |
| 5.....    | 111.25              |
| 6.....    | 110.60              |

(807) In Fig. 72,  $AC$  is an ascending grade of 1 per cent., and  $CB$  is a descending grade of 0.8 per cent., which

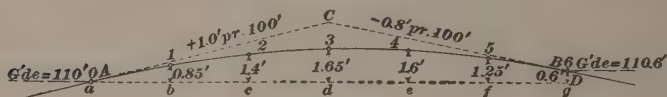


FIG. 72.

are the grades specified in Question 806. To draw these grade lines, first draw a horizontal line  $AD$  6 in. long, which will include both grade lines to a scale of 100 ft. to the inch. Divide this line into six equal parts, with the letters  $a, b, c$ , etc., at the points of division. Now,  $d$  being 300 ft. from  $A$ , the height of the original grade line above  $d$  is the rate of grade.  $g = 1.0 \text{ ft.} \times 3 = 3 \text{ ft.}$ , which distance we scale off above  $d$  to a vertical scale of 5 ft. to the inch, locating the point  $C$ . The grade of  $CB$  is  $-0.8 \text{ ft. per } 100 \text{ ft.}$ . Consequently,  $B$ , which is 300 ft. from  $C$ , is  $0.8 \text{ ft.} \times 3 = 2.4 \text{ ft.}$  below  $C$ , and the height of  $B$  above  $AD$  is equal to  $3.0 \text{ ft.} - 2.4 \text{ ft.} = 0.6 \text{ ft.}$ . We scale off above  $D$  the distance  $0.6 \text{ ft.}$ , locating  $B$ . Joining  $AC$  and  $BC$ , we have the original grade lines, which are to be united by a vertical curve. Now, the elevation of the grade at Sta. 0 is 110 ft. The line  $AD$  has the same elevation. We have already determined the heights of the curve above this line at the several stations on the curve. Accordingly, we lay off these distances, viz., at  $b$ , corresponding to Sta. 1,  $0.85 \text{ ft.}$ ; at  $c$ , Sta. 2,  $1.4 \text{ ft.}$ ; at  $d$ , Sta. 3,  $1.65 \text{ ft.}$ , etc., marking each

point so determined by a small circle. The curved line joining these points is the vertical curve required.

(808) See Art. **1443.**

(809) See Art. **1444.**

(810) See Art. **1446.**

(811) See Art. **1447.**

(812) See Art. **1451.**





# RAILROAD CONSTRUCTION.

(QUESTIONS 813-872)

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(813) See Art. 1454.

(814) See Art. 1455.

(815) The slope given to embankment is  $1\frac{1}{2}$  horizontal to 1 vertical, and the slope usually given to cuttings is 1 horizontal to 1 vertical. (See Art. 1457 and Figs. 380 and 381.)

(816) The height of the instrument being 127.4 feet and the elevation of the grade 140 feet, the instrument is below grade to an amount equal to the difference between 140 and 127.4 feet, which is 12.6 feet. The rod reading for the right slope being 9.2 feet, the surface of the ground is 9.2 feet below the instrument, which we have already shown to be 12.6 feet below grade. Hence, the distance which the surface of the ground is below grade is the sum of 12.6 and 9.2 which is 21.8 feet, which we describe as a *fill* of 21.8 feet. Ans. The side distance, i. e., the distance at which we must place the slope stake from the center line, is  $1\frac{1}{2}$  times 21.8 feet, the amount of the fill, plus  $\frac{1}{2}$  the width of the roadway, or 8 feet. Therefore, side distance =  $\frac{3 \times 21.8}{2} + 8 = 40.7$  feet. Ans.

(817) The height of instrument H. I. being 96.4 feet, and the rod reading at the surface of the ground 4.7 feet, the elevation of the surface of the ground is  $96.4 - 4.7 = 91.7$  feet. As the elevation of grade is 78.0 feet, the amount of cutting is the difference between 91.7 and  $78.0 = 13.7$  feet. Ans.

(818) The elevation of the surface of the ground is the height of instrument minus the rod reading; i. e.,  $96.4 - 8.8 = 87.6$  feet. The elevation of grade is 78.0 feet; hence, the cutting is  $87.6 - 78.0 = 9.6$  feet. The slope of the cutting is 1 foot horizontal to 1 foot vertical; hence, from the foot of the slope to its outer edge is 9.6 feet. Ans. To this we add one-half the width of the roadway, or 9 feet, giving for the side distance  $9.6 + 9 = 18.6$  feet. Ans.

(819) See Art. 1459.

(820) See Art. 1460.

(821) See Art. 1461.

(822) We substitute the given quantities in formula 102  $A = C\sqrt{M}$  (see Art. 1461), in which  $A$  = the area of the culvert opening in square feet;  $C$  the variable coefficient, and  $M$  the area of the given water shed in acres. We accordingly have  $A = 1.8\sqrt{400} = 36$  square feet. Ans.

(823) Applying rule I, Art. 1462, we obtain the distance from the center line to the face of the culvert as follows: To the height of the side wall, viz., 4 feet, we add the thickness of the covering flags and the height of the parapet—each 1 foot, making the total height of the top of parapet  $4 + 2 = 6$  feet. 28 feet, the height of the embankment at the center line, minus 6 feet = 22 feet. With this as the height of the embankment, we calculate the side distance as in setting slope stakes  $1\frac{1}{2}$  times 22 feet = 33 feet.

One-half the width of roadway is  $\frac{16}{2} = 8$  feet.  $33 + 8 = 41$  feet.

To this distance we add 18 inches, making 42 feet 6 inches. As the embankment is more than 10 feet in height, we add to this side distance 1 inch for each foot in height above the parapet, i. e., 22 inches = 1 foot 10 inches. Adding 1 foot 10 inches to 42 feet 6 inches, we have for the total distance from the center line to the face of the culvert 44 feet 4 inches. Ans.

We find the length of the wing walls by applying rule II.

**Art. 1462.** The height of top of the covering flags is 5 feet.  $1\frac{1}{2}$  times 5 feet = 7.5 feet. Adding 2 feet, we have length of the wing walls, i. e., the distance from inside face of the side walls to the end of the wing walls,  $7.5 + 2 = 9$  feet 6 inches. Ans.

**(824)** The span of a box culvert should not exceed 3 feet. When a larger opening is required, a double box culvert with a division wall 2 feet in thickness is substituted.

**(825)** See Art. **1462**.

**(826)** See Art. **1462**.

**(827)** See Art. **1463**.

**(828)** See Art. **1465**.

**(829)** The thickness of the base should be  $\frac{4}{10}$  of the height. The height is 16 feet and the thickness of the base should be  $\frac{4}{10}$  of 16 feet, or 6.4 feet. Ans.

**(830)** See Art. **1468**.

**(831)** See Art. **1468**.

**(832)** Trautwine's formula for finding the depth of keystone (see formula **103**, Art. **1469**), is as follows:

$$\text{depth of keystone in feet} = \frac{\sqrt{\text{radius of arch} + \frac{1}{2} \text{span}}}{4} + 0.2 \text{ foot.}$$

In this example the arch being semicircular, the radius and half-span are the same. Substituting known values in the given formula, we have

$$\text{depth of keystone} = \frac{\sqrt{15 + 15}}{4} + 0.2 \text{ foot} = 1.57 \text{ feet. Ans.}$$

Applying Rankine's formula (formula **104**), depth of keystone =  $\sqrt{.12 \text{ radius}}$ , we have depth of keystone =  $\sqrt{.12 \times 15} = 1.34 \text{ feet. Ans.}$

(833) Applying the rule given in Art. **1469**, we find the length of radius is equal to  $\frac{19^2 + 12^2}{24} = \frac{505}{24} = 21.04$  feet.  
Ans.

(834) Applying formula **105**, Art. **1470**, we have thickness of abutment at spring line  $= \frac{12 \text{ feet}}{5} + \frac{8 \text{ feet}}{10} + 2 \text{ feet} = 5.2$  feet.  
Ans.

(835) See Art. **1472**.

(836) See Art. **1471**.

(837) See Art. **1472**.

(838) See Art. **1473**.

(839) See Art. **1473**.

(840) See Art. **1474**.

(841) See Art. **1475**.

(842) See Art. **1475**.

(843) They should be laid in the radial lines of the arch.  
See Art. **1477**.

(844) See Art. **1477**.

(845) Until the arch is half built, the effect of the weight of the arch upon the centering is to cause a lifting at the crown. After that point is passed, the effect of the weight is to cause a lifting of the haunches.

(846)  $120^\circ$ . Ans.

(847) See Art. **1480**.

(848) According to the rule given in Art. **1480**, the thickness of the base should be  $\frac{4}{10}$  of the vertical height.  $10 \text{ feet} \times \frac{4}{10} = 4$  feet. Ans.

(849) See Art. **1480**.

(850) The friction of the backing against the wall adds considerably to its stability.

(851) See Art. 1481.

(852) See Art. 1482.

(853) See Art. 1483 and Fig. 401.

(854) See Art. 1484.

(855) The line  $d c$  in Fig. 73 forms an angle of  $33^{\circ} 41'$  with the horizontal  $d h$  and is the natural slope of earth.

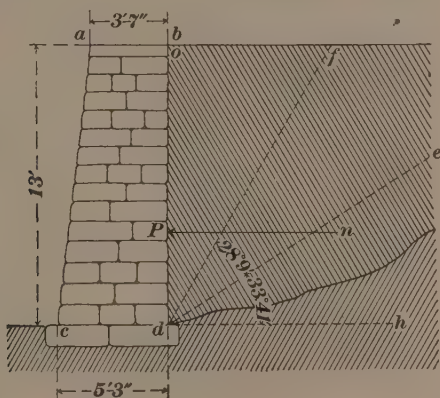


FIG. 73.

The line  $d f$  bisects the angle  $o d c$ . The angle  $o d f$  is called the *angle*, the slope  $d f$  is called the *slope*, and the triangular prism  $o d f$  is called the *prism* of maximum pressure.

(856) See Art. 1486.

(857) See Art. 1486.

(858) From Fig. 73, given above, we have, by applying formula 106, Art. 1486,

$$\text{perpendicular pressure } n P = \frac{\text{the weight of the triangle of earth } o d f \times o f}{\text{the vertical height } o d}$$

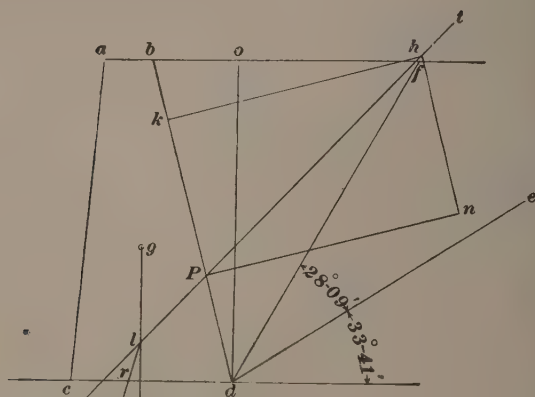


FIG. 74.

(859) First *gravity*, i. e., the weight of the wall itself, and second *friction* produced by the weight of the wall upon its foundation and by the pressure of the backing against the wall.

(860) The angle of wall friction is the angle at which a plane of masonry must be inclined in order that dry sand and earth may slide freely over it.

(861) The base  $b f$ , Fig. 74, of the triangle  $b d f$  is 12.73 feet, and the altitude  $o d$  is 16 feet. Hence, area of  $b d f$  is  $12.73 \times 8 = 101.84$  square feet. Taking the weight of the backing at 120 pounds per cubic foot, we have the weight of  $b d f = 101.84 \times$

120 = 12,221 pounds. Multiplying this weight by  $s f = 8.56$  feet, we have  $12,221 \times 8.56 = 104,612$  pounds, which, divided by  $o d$ , 16 feet, = 6,538 pounds = the pressure of the backing. This pressure to a scale of 4,000 pounds to the inch equals 1.63 inches.  $P$ , the center of pressure, is at  $\frac{1}{3}$  of the height of  $b d$  measured from  $d$ . At  $P$  erect a perpendicular to the back of the wall. Lay off on this perpendicular the distance  $P n = 1.63$  in. Draw  $P t$ , making the angle  $n P t = 33^\circ 41' =$  the angle of wall friction. At  $n$  draw a perpendicular to  $P n$ , intersecting the line  $P t$  in  $h$ . Draw  $h k$ , completing the parallelogram  $n h k P$ ;  $h n$ , or its equal  $k P$ , will represent the friction of the backing against the wall and the diagonal  $h P$ , which, to the same scale, = 7,857 pounds, will be the resultant of the pressure of the backing and the friction. Produce  $P h$  to  $s$ . The section  $a b d c$  of the wall is a trapezoid. Its area is 84 square feet, which, multiplied by 154 pounds, the weight of rubble per cubic foot, gives 12,936 pounds, as the weight of the wall, which, to a scale of 4,000 pounds to the inch, = 3.23 inches. Find the center of gravity  $g$  of the section  $a b d c$ , as explained in Art. 1488. Through  $g$  draw the vertical line  $g i$ , intersecting the prolongation of  $P h$  in  $l$ . Lay off from  $l$ , on  $g i$ , the distance  $l v$ , 3.23 inches = weight of the wall, and on  $l s$ , the distance  $l m = 1.96$  inches, the length of the resultant  $P h$ ; complete the parallelogram  $l m u v$ . The diagonal  $l u$  is the resultant of the weight of the wall and the pressure. The distance  $c r$  from the toe  $c$  to the point where the resultant  $l u$  cuts this base is 3.6 feet, or nearly  $\frac{1}{2}$  of the base  $c d$ . This guarantees abundant stability to the retaining wall.

The distance  $o f$  is obtained as follows:  $c d = 8$  feet; batter of  $c a = 1$  inch for each foot of length of  $o d = 16$  inches; hence,  $a o = 8$  feet — 16 inches = 6 feet 8 inches;  $a b = 2.5$  feet; therefore,  $o f = 12.73 - (6 \text{ feet } 8 \text{ inches} - 2.5 \text{ feet}) = 8.56$  feet.

(862) See Art. 1491.

(863) See Art. 1491 and Figs. 409, 410, and 411.



(864) See Art. 1492.

(865) See Art. 1493.

(866)  $\frac{540, \text{ the number of working minutes in a day, }}{1.25 + 4} =$

102.9 trips.  $\frac{102.9}{14} = 7.35$  cubic yards per man;  $\frac{\$1.15}{7.35} =$

15.65 cents per cubic yard for wheeling. One picker serves 5 wheelbarrows; he will accordingly loosen  $7.35 \times 5 = 36.75$  cubic yards. Cost of picking will, therefore, be  $\frac{\$1.15}{36.75} =$

3.13 cents per cubic yard. There are 24 men in the gang, one-sixth of whom are pickers. There are, consequently, 20 wheelers, who together will wheel in one day  $7.35 \times 20 = 147$  cubic yards. One foreman at \$2.00 and one water-carrier at 90 cents per day are required for such a gang. Their combined wages are \$2.90. The cost of superintendence and water-carrier is, therefore,  $\frac{\$2.90}{147} = 1.97$  cents per cubic yard. Use of tools and wheelbarrows is placed at  $\frac{1}{2}$  cent per cubic yard.

Placing items of cost in order, we have

|                                  |                             |
|----------------------------------|-----------------------------|
| Cost of wheeling.....            | 15.65 cents per cubic yard. |
| Cost of picking.....             | 3.13 cents per cubic yard.  |
| Cost of water-carrier and super- |                             |
| intendence.....                  | 1.97 cents per cubic yard.  |
| Use of tools and wheelbarrows    | .50 cent per cubic yard.    |
|                                  | <hr/>                       |
|                                  | 21.25 cents per cubic yard. |

(867) The number of carts loaded by each shoveler (Art. 1494) is  $\frac{420}{5} = 84$ .  $84 \div 3 = 28$  cubic yards handled per day by each shoveler. The cost of shoveling is, therefore,  $\frac{120}{28} = 4.29$  cents per cubic yard. The number of cart trips per day is  $\frac{600}{7 + 4} = 54.54$ . As a cart carries  $\frac{1}{3}$  cubic yard, each cart will in one day carry  $\frac{54.54}{3} = 18.18$  cubic

yards. As cart and driver cost \$1.40 per day, the cost of hauling is  $\frac{\$1.40}{18.18} = 7.7$  cents per cubic yard. Foreman and water-carrier together cost \$3.25. The gang contains 12 carts, which together carry  $18.18 \times 12 = 218.2$  cubic yards.  $\frac{\$3.25}{218.2} = 1.49$  cents per cubic yard for water-carrier and superintendence. As loosening soil costs 2 cents per cubic yard, dumping and spreading 1 cent per cubic yard, and wear of carts and tools  $\frac{1}{2}$  cent per cubic yard, we have the total cost per cubic yard as follows:

|                                         |                             |
|-----------------------------------------|-----------------------------|
| Loosening soil.....                     | 2.00 cents per cubic yard.  |
| Shoveling into carts.....               | 4.29 cents per cubic yard.  |
| Hauling .....                           | 7.70 cents per cubic yard.  |
| Superintendence and water-carrier ..... | 1.49 cents per cubic yard.  |
| Wear and tear of carts and tools,       | 0.50 cent per cubic yard.   |
| Dumping and spreading.....              | 1.00 cent per cubic yard.   |
| Cost for delivering on the dump,        | 16.98 cents per cubic yard. |

(868) See Art. **1499.**

(869) See Art. **1499.**

(870) See Art. **1500.**

(871) See Art. **1500.**

(872) In carrying the steam a long distance through iron pipes its pressure is greatly reduced by condensation, whereas compressed air may be carried a great distance without suffering any loss in pressure excepting that due to friction and leakage.



# RAILROAD CONSTRUCTION.

(QUESTIONS 873-946.)

(873) See Art. **1503**.

(874) See Art. **1504**.

(875) See Art. **1504**.

(876) See Art. **1505** and Figs. 426 and 428.

(877) As  $60^{\circ}$  F. is assumed as normal temperature, and as the temperature at the time of measuring the line is  $94^{\circ}$ , we must, in determining the length of the line, make an allowance for expansion due to an increase of temperature equal to the difference between  $60^{\circ}$  and  $94^{\circ}$ , or  $34^{\circ}$ . The allowance per foot per degree, as stated in Art. **1505**, is .0000066 ft., and for  $34^{\circ}$  the allowance per foot is  $.0000066 \times 34 = .0002244$  ft.; for 89.621 ft. the allowance is  $.0002244 \times 89.621 = 0.020$  ft. The normal length of the line will, therefore, be  $89.621 + .020 = 89.641$  ft. Ans.

(878) Let the line  $AB$  in Fig. 75 represent the slope distance as measured, viz., 89.72 ft. This line will, together with the difference of elevation between the extremities  $A$  and  $B$ , viz., 11.44 ft., and the

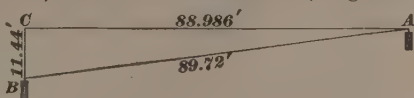


FIG. 75.

required horizontal distance  $AC$ , form a right-angled triangle, right-angled at  $C$ . By rule **1**, Art. **754**, we have

$\sin A = \frac{11.44}{89.72} = .12751$ ; whence,  $A = 7^{\circ} 20'$ . Again, by

rule **3**, Art. **754**,  $\cos 7^{\circ} 20' = \frac{AC}{89.72}$ ; whence,  $.99182 =$

$\frac{AC}{89.72}$ , and  $AC = 89.72 \times .99182 = 88.986$  ft. Ans.

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(879) See Art. **1508**.

(880) See Art. **1511**.

(881) See Art. **1511** and Figs. 435, 436, 445, and 446.

(882) See Art. **1513**.

(883) See Art. **1514**.

(884) See Art. **1517**.

(885) If the elevation of the grade of the station is 162 ft. and the height of the tunnel section is 24 ft., the elevation of the tunnel roof at that station is  $162 + 24 = 186$  ft. The height of instrument is 179.3 ft., and when the roof at the given station is at grade, the rod reading will be  $186 - 179.3 = 6.7$  ft. Ans.

(886) See Art. **1515**.

(887) See Art. **1517** and Fig. 448.

(888) See Art. **1520** and Fig. 452.

(889) See Art. **1523**.

(890) See Art. **1525**.

(891) See Art. **1526**.

(892) The area of an 18-inch air pipe is  $1.5^2 \times .7854 = 1.77$  sq. ft. At a velocity of 13 ft. per second, the amount of foul air removed from the heading per second is  $1.77 \times 13 = 23.01$  cu. ft. And as each cubic foot of foul air removed is replaced by one of pure air, in 1 minute the amount of pure air furnished is  $23.01 \times 60 = 1,380.6$  cu. ft. As each man requires 100 cu. ft. of pure air per minute, there will be a supply for as many laborers as 100 is contained times in 1,380.6, which is 13.8, say 14. Ans.

(893) See Art. **1528**.

(894) See Art. **1533** and Fig. 455.

(895) See Art. **1535** and Fig. 457.

(896) See Art. 1536 and Fig. 458.

(897) The height of embankment is 21 ft.; the culvert opening, 3 ft. in height, and the covering flags and parapet each 1 ft. in height, making the top of parapet 5 ft. above the foundation. In Fig. 76 the angle  $B A L$  is  $75^\circ$  and represents the skew of the culvert. Drawing the line  $A D$  at right angles to the center line  $A C$ , we have the angle  $B A D = 90^\circ - 75^\circ = 15^\circ$ . If the culvert were built at right angles to the center line, the side distance  $A D$  from the

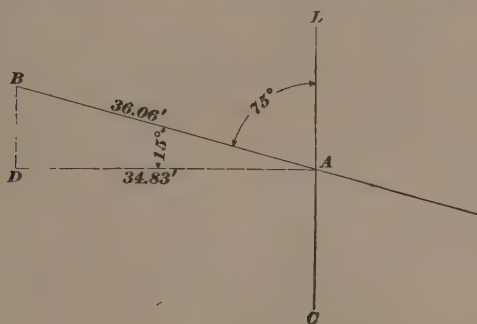


FIG. 76.

center line to the end of the culvert would be as follows: 21 ft.  $-$  5 ft. = 16 ft.  $16 \text{ ft.} \times 1\frac{1}{2} = 24 \text{ ft.}$  Adding 1.5 ft., and, in addition, 1 in. for each foot of embankment above the parapet, i. e., 16 in., or 1.33 ft., we have  $24 + 1.5 + 1.33 = 26.83 \text{ ft.}$  Adding 8 ft., one-half the width of the roadway, we have  $26.83 + 8 = 34.83 \text{ ft.} = AD$ . At  $D$  erect the perpendicular  $DB$ . In the right-angled triangle  $ADB$ , we have  $\cos A = \frac{AD}{AB}$ , i. e.,  $\cos 15^\circ = \frac{34.83}{AB}$ ; whence,  $.96593 = \frac{34.83}{AB}$ , and  $AB = \frac{34.83}{.96593} = 36.06 \text{ ft.}$  Ans.

(898) See Art. 1541.

(899) See Art. 1541 and Fig. 462.

(900) See Art. 1542.

(901) See Art. 1544.

(902) The rod reading for grade will be the difference between the height of instrument and the elevation of the grade for the given station ; i. e.,  $125.5 - 118.7 = 6.8$  ft.

Ans.

(903) See Art. 1547.

(904) See Art. 1548.

(905) The skew of a bridge is the angle which its center line makes with the general direction of the channel spanned by the bridge.

(906) See Art. 1549.

(907) The length of  $A B$  is determined by the principles of trigonometry stated in Art. 1243, from the following proportion :  $\sin 46^\circ 55' : \sin 43^\circ 22' :: 421.532 : A B$ ; whence,  $A B = 396.31$  ft. Ans.

(908) See Art. 1551.

(909) See Art. 1553.

(910) See Art. 1554 and Figs. 465 and 466.

(911) The depth of the center of gravity of the water below the surface is  $\frac{10}{2} = 5$  ft. Applying the law for *lateral pressure*, given in Art. 1554, we have

(a) Total water pressure  $= 10 \times 5 \times 40 \times 62.5 = 125,000$  lb.

Ans.

(b) Taking a section of the dam 1 ft. in length, we have  
lateral pressure  $= 10 \times 5 \times 62.5 = 3,125$  lb.

The *center* of water pressure is at  $\frac{1}{3}$  the depth of the water above the bottom, i. e., at  $10 \div 3 = 3\frac{1}{3}$  ft.

The moment of water pressure about the inner toe of the dam will, therefore, be  $3,125 \times 3\frac{1}{3} = 10,417$  ft.-lb. Ans.

(912) The volume of a section of the cofferdam 1 ft. in length is  $11 \times 1 \times 5 = 55$  cu. ft., which, at 130 lb. per cubic foot, will weigh  $55 \times 130 = 7,150$  lb.



(a) The moment of resistance of the cofferdam is the product of its weight, viz., 7,150 lb. multiplied by the perpendicular distance from the inner toe of the dam to the vertical line drawn through the center of gravity of the dam. This perpendicular distance is 2.5 ft. The moment of resistance is, therefore,  $7,150 \times 2.5 = 17,875$  ft.-lb. Ans.

(b) The factor of safety of the cofferdam is the quotient of the moment of resistance of the dam divided by the moment of water pressure. Hence,  $17,875 \div 10,417 = 1.71$ . This calculation does not include the additional weight and resistance of the piles and timber enclosing the puddled wall, which will greatly increase the factor of safety.

(913) See Art. **1555**.

(914) See Art. **1555**.

(915) See Art. **1556**.

(916) See Art. **1557**.

(917) See Art. **1559**.

(918) See Arts. **1560** and **1561**.

(919) See Arts. **1563** and **1564**.

(920) As the sides of the bridge piers are always, and the ends often, battered, the deeper the foundation the greater will be the dimensions of the caisson plan. The thickness of the walls and deck of the caisson will depend upon the weight of the masonry and the bridge which they must support.

(921) To reduce the friction of the earth against its sides while sinking.

(922) See Art. **1566**.

(923) See Art. **1566**.

(924) See Art. **1568**.

(925) See Art. **1568**.

(926) See Art. **1570**

(927) Multiplying 70 ft., the depth of the water, by the decimal .434 and adding 15 lb., the pressure of the atmosphere, we have  $70 \times .434 = 30.38$ .  $30.38 + 15 = 45.38$  lb.

Ans.

(928) Formula 109,  $L = \frac{2wh}{S+1}$ . (See Art. 1572.)

(929) See Art. 1573.

(930) The striking force of the hammer is equal to 3,500 lb., the weight of the hammer multiplied by 30, the number of feet in its fall, or  $3,500 \times 30 = 105,000$  ft.-lb.

Ans.

(931) See Art. 1575.

(932) See Art. 1576.

(933) See Art. 1577.

(934) See Art. 1578.

(935) See Art. 1580.

(936) Applying formula 109,  $L = \frac{2wh}{S+1}$  (see Art. 1572), in which  $L$  = the safe load in tons,  $w$  = the weight of the hammer in tons,  $h$  = the height of the fall of the hammer in feet, and  $S$  = the average penetration of the last three blows; we have, by substituting known values in the formula, safe load  $L = \frac{3 \times 22}{1.5} = 44$  tons. Ans.

(937) Applying formula 109,  $L = \frac{2wh}{S+1}$ , we find the safe load of each pile as follows: First pile,  $L = \frac{3.3 \times 35}{.75+1} = 66$  tons; second pile,  $L = \frac{3.3 \times 35}{.8+1} = 64.166$  tons; third pile,  $L = \frac{3.3 \times 35}{.875+1} = 61.6$  tons; total safe load of three piles = 191.77 tons. Ans.

(938) See Art. 1585.

- (939) See Art. **1585.**
- (940) See Art. **1586.**
- (941) See Art. **1589** and Figs. 484, 485, and 486.
- (942) See Art. **1590.**
- (943) See Art. **1591**
- (944) See Art. **1591.**
- (945) See Art. **1591.**
- (946) See Art. **1592.**



# TRACK WORK.

(QUESTIONS 947-1016.)

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(947) See Art. **1593.**

(948) See Art. **1595.**

(949) See Art. **1596.**

(950) See Art. **1597.**

(951) See Art. **1599.**

(952) See Art. **1600.**

(953) See Arts. **1602** and **1603.**

(954) See Art. **1606.**

(955) See Art. **1607.**

(956) See Art. **1608.**

(957) See Art. **1609.**

(958) The coefficient of expansion is .00000686 per degree per lineal foot (see Art. **1611**). As the temperature of the bar is  $85^{\circ}$  and normal temperature is  $60^{\circ}$ , the elongation per foot due to increase of temperature is equal to  $85 - 60 = 25 \times .00000686 = .0001715$  of a foot for each foot of length of the bar, and the total elongation is equal to  $.0001715 \times 30.016 = .00515$  ft., say  $.005$  ft.  $= \frac{1}{16}$  in. The normal length of the bar is, therefore,  $30.016 - .005 = 30.011$  ft. Ans.

(959) See Art. **1611.**

(960) See Art. **1612.**

(961) See Art. **1615.**

(962) See Art. **1617**.

(963) See Art. **1618**.

(964) See Art. **1619**.

(965) See Art. **1619**.

(966) See Figs. 507, Art. **1618**, and 510, Art. **1619**.

(967) See Art. **1625**.

(968) See Art. **1631**.

(969) See Art. **1638**.

(970) See Art. **1642**.

(971) See Art. **1650** and Fig. 513

(972) See Art. **1650**.

(973) See Art. **1655**.

(974) See Art. **1656**.

(975) See Art. **1659**.

(976) See Art. **1662**.

(977) The distance between rail centers is 4 ft. 11 in., which, expressed in feet and the decimal of a foot, is 4.916 ft. The radius of an  $8^\circ$  curve is 716.78 ft. Applying rule **2**, under Art. **1664**, we have

$$\text{excess of length of outer rail} = \frac{4.916 \times 425}{716.78} = 2.91 \text{ ft. Ans.}$$

(978) The chord  $c = 30$  ft.; the radius  $R = 955.37$  ft. Applying formula **112**, Art. **1665**,

$$m = \frac{c^2}{8R},$$

and substituting known values, we have

$$m = \frac{30^2}{8 \times 955.37} = \frac{900}{7,642.96} = .118 \text{ ft., nearly } 1\frac{1}{2} \text{ in. Ans.}$$

(979) We find in Table 32, Art. **1665**, that the middle ordinate of a 50-ft. chord of a  $1^\circ$  curve is  $\frac{5}{8}$  in. The middle ordinate of the given chord is  $3\frac{1}{2}$  in., and the

degree of the given curve is, therefore, the quotient, or,  $3\frac{1}{2} \div \frac{5}{8} = 5.6^\circ = 5^\circ 36'$ . The degree of the given curve is probably  $5^\circ 30'$ . - Ans.

(980) See Art. 1667.

(981) See Art. 1669.

(982) Formula 113,  $c = 1.587 V$ . (See Art. 1670.)

(983) Applying formula 113,  $c = 1.587 V$  (see Art. 1670), in which  $c$  is equal to the chord whose middle ordinate  $m$  is equal to the required elevation, and  $V$  the velocity of the train in miles per hour, we have

$$c = 1.587 \times 35 = 55.5 \text{ ft.}$$

We next find the middle ordinate  $m$  by applying formula 112, Art. 1665,

$$m = \frac{c^2}{8R},$$

in which  $c = 55.5$  ft. and  $R = 573.69$  ft. Substituting known values, we have

$$m = \frac{55.5^2}{8 \times 573.69} = \frac{3,080}{4,589} = .67 \text{ ft.} = 8 \text{ in., nearly. Ans.}$$

(984) For each half inch of curve elevation we add one rail length to the elevated approach, which gives for a 4-in. elevation  $4 \div \frac{1}{2} = 8$  rail lengths, equal to  $8 \times 30 = 240$  ft. Ans.

(985) See Art. 1674.

(986) See Art. 1676 and Fig. 522.

(987) See Art. 1679.

(988) See Art. 1681 and Figs. 525, 526, and 527.

(989) See Art. 1682 and Fig. 528.

(990) See Art. 1683 and Fig. 529.

(991) See Art. 1684.

(992) See Art. 1685 and Fig. 530.

(993) See Art. 1686 and Fig. 531.

(994) See Art. 1687.

(995) See Art. 1687 and Fig. 532.

(996) See Art. 1688 and Fig. 533.

(997) See Art. 1689 and Fig. 535.

(998) See Art. 1690 and Fig. 536.

(999) See Art. 1691 and Fig. 538.

(1000) Applying formula 115, given in Art. 1692,

$$\text{frog number} = \sqrt{\text{radius} \div \text{twice the gauge}},$$

and substituting known values, we have

$$\text{frog number} = \sqrt{602.8 \div 9.417}; \text{ whence,}$$

$$\text{frog number} = 8, \text{ almost exactly. Ans.}$$

(1001) Applying formula 117, given in Art. 1692,

$$\text{radius} = \text{twice the gauge} \times \text{square of frog number},$$

and substituting known values, we have

$$\text{radius} = (4 \text{ ft. } 8\frac{1}{2} \text{ in.}) \times 2 \times 6^2 = 9.417 \times 36 = 339 \text{ ft.}$$

Ans.

To find the degree of the required curve, we divide 5,730 ft., the radius of a  $1^\circ$  curve, by 339, the length of the required radius, which gives  $16.902^\circ = 16^\circ 54'$ , the degree of the required curve.

(1002) From table of Tangent and Chord Deflections, we find the tangent deflection of an  $18^\circ$  curve is 15.64 ft. Calling the required frog distance  $x$ , we have, from Art. 1692 and Fig. 540, the following proportion:

$$15.64 : 4.75 :: 100^2 : x^2;$$

$$\text{whence, } x^2 = \frac{100^2 \times 4.75}{15.64} = \frac{47,500}{15.64} = 3,037.08,$$

$$\text{and } x = 55.1 \text{ ft. Ans.}$$

The frog angle is equal to the central angle of a 55.1 ft. arc of an  $18^\circ$  curve. As  $18^\circ$  is the central angle of a 100-ft. arc, the central angle of an arc of 55.1 ft. is  $\frac{55.1}{100}$  of  $18^\circ = 9^\circ 55'$ . Ans.



(1003) This example comes under Case I of Art. 1693. The sum of the tangent deflections of the two curves for chords of 100 ft. is equal to the tangent deflection of a  $16^{\circ} 30'$  curve for a chord of 100 ft. This deflection, we find from the table of Tangent and Chord Deflections, is 14.35 ft. Calling the required frog distance  $x$ , we have, from Art. 1692, the following proportion:

$$14.35 : 4.75 :: 100^2 : x^2;$$

$$\text{whence, } x^2 = \frac{100^2 \times 4.75}{14.35} = \frac{47,500}{14.35} = 3,310,$$

$$\text{and } x = 57.5 \text{ ft. Ans.}$$

As the central angle subtended by a 100-ft. chord is  $16^{\circ} 30'$ , the angle subtended by a chord of 1 ft. is  $\frac{16^{\circ} 30'}{100} = 9.9'$ , and for a chord of 57.5 ft. the central angle is  $9.9' \times 57.5 = 569.25' = 9^{\circ} 29\frac{1}{4}'$ , the required frog angle.

(1004) This example comes under Case II of Art. 1693, in which the curves deflect in the same direction. As the main track curve is  $4^{\circ}$  and the turnout curve  $12^{\circ}$ , the rate of their deflection from each other is equal to the deflection of a  $12^{\circ} - 4^{\circ}$ , or of an  $8^{\circ}$  curve from a straight line. From the table of Tangent and Chord Deflections, we find the tangent deflection of an  $8^{\circ}$  curve for a chord of 100 ft. is 6.98 ft. Now, the distance between the gauge lines at the head-block is fixed at 5 in. = .42 ft., and calling the required head-block distance  $x$ , we have the proportion

$$6.98 : 0.42 :: 100^2 : x^2;$$

$$\text{whence, } x^2 = 601.7, \text{ and}$$

$$\text{head-block distance } x = 24.5 \text{ ft. Ans.}$$

(1005) Multiply the spread of the heel by the number of the frog; the product will be the distance from the heel to the theoretical point of frog.

(1006) See Art. 1694.

$$(1007) 60 \times 12 = 720 \text{ in. } 720 \div 15 = 48. \text{ Ans.}$$

(1008) 8 ft. 6 in. = 102 in. 15 ft. 3 in. = 183 in. 183 in. - 102 in. = 81 in.  $81 \text{ in.} \div 48 = 1.69 \text{ in.} = 1\frac{11}{16} \text{ in.}$  Ans.

(1009) See Art. 1698.

(1010) We find the crotch frog distance as follows: From the table of Tangent and Chord Deflections, we find the tangent deflection of a 100-ft. chord of a  $10^\circ$  curve is 8.72 ft. One-half the gauge is 2.35 ft. Calling the crotch frog distance  $x$ , we have the proportion

$$8.72 : 2.35 :: 100^2 : x^2;$$

whence,  $x^2 = \frac{100^2 \times 2.35}{8.72} = 2,695$ , nearly,

and  $x = 51.9 \text{ ft.}$  Ans.

The central angle for a chord of 51.9 ft. is  $6' \times 51.9 = 311.4' = 5^\circ 11.4'$ , and the angle of the crotch frog is  $5^\circ 11.4' \times 2 = 10^\circ 22.8'$ . Ans.

(1011) See Art. 1700.

(1012) See Art. 1710.

(1013) See Art. 1711.

(1014) See Art. 1712.

(1015) See Art. 1714.

(1016) See Art. 1715.

# RAILROAD STRUCTURES.

(QUESTIONS 1017-1082.)

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(1017) Eight years.

(1018) See Art. **1731**.

(1019) See Art. **1732**.

(1020) See Art. **1734**.

(1021) See Art. **1734**.

(1022) See Art. **1735**.

(1023) Test piles should be driven at frequent intervals and the required lengths determined by actual measurement.

(1024) See Art. **1739** and Fig. 558.

(1025) See Art. **1739**.

(1026) See Art. **1741** and Fig. 561.

(1027) See Art. **1742**.

(1028) See Art. **1742** and Figs. 562 to 567, inclusive.

(1029) See Art. **1745** and Fig. 565.

(1030) See Art. **1746** and Fig. 566.

(1031) See Art. **1748** and Fig. 567.

(1032) See Art. **1749** and Figs. 568 and 569.

(1033) See Art. **1752** and Figs. 577 and 578.

(1034) See Art. **1753** and Figs. 579 to 584, inclusive.

(1035) See Art. **1754** and Figs. 585 to 587, inclusive.

(1036) See Art. **1756** and Figs. 588 to 591, inclusive.

(1037) See Art. **1756** and Fig. 592.

(1038) See Art. **1757**.

(1039) See Art. **1758** and Fig. 592.

(1040) See Art. **1759**.

(1041) See Art. **1759**.

(1042) See Art. **1760**.

(1043) See Art. **1760** and Figs. 598 to 601, inclusive.

(1044) See Art. **1761** and Fig. 604.

(1045) See Art. **1763** and Figs. 606 and 607.

(1046) See Art. **1767** and Figs. 608, 609, and 610.

(1047) See Art. **1770**.

(1048) See Art. **1775** and Figs. 617 and 618.

(1049) See Art. **1778**.

(1050) See Art. **1780**.

(1051) See Art. **1787**.

(1052) See Art. **1789** and Fig. 622.

(1053) See Art. **1800**. From Table 52, Art. **1802**, we find the constant for cross-breaking center loads for spruce is 450. Applying formula **127**, Art. **1800**, we have

$$\frac{10 \times 144}{18} \times 450 = 36,000 \text{ lb. Ans.}$$

(1054) See Art. **1803**.

(1055) The constant for center breaking loads for yellow pine is 550, Table 52, Art. **1802**. Applying the rule given in Art. **1804**, we have  $\frac{50,000 \times 20}{550} = 1,818$ . The cube-root of 1,818 is 12.2 nearly. Hence, the beam should be  $12\frac{1}{4}$  inches square. Ans.

On account of the great size of this beam, its own weight constitutes a considerable factor of the breaking load, and to provide for this additional weight we must increase the size of the beam as directed in Art. **1804**.

Yellow pine weighs, on an average, 65 lb. per cu. ft. The beam between supports contains 20.8 cu. ft. Its weight is, therefore,  $20.8 \times 65 = 1,352$  lb. Applying the proportion

given in Art. **1804**, and denoting the required addition in width by  $x$ , we have

$$50,000 : \frac{1,352}{2} :: 12.2 : x;$$

whence,  $x = 0.16$  in. The beam should, therefore, be  $12.2 + 0.16 = 12.36$  inches square, equal to about  $12\frac{3}{8}$  inches.

(**1056**) A safe center load of 16,000 lb. with a factor of safety of 5, will call for a center breaking load of  $16,000 \times 5 = 80,000$  lb. We next find, by Art. **1804**, the side of a square beam which will break under this center load of 80,000 lb., and we have  $\frac{80,000 \times 16}{550} = 2,327$ , the cube root of which is 13.25, nearly. Hence, the side of the required square beam is  $13\frac{1}{4}$  inches. Ans. •

(**1057**) The constant for center breaking loads for spruce is 450. (See Table 52, Art. **1802**.) Applying the rule given in Art. **1806**, we have

$$\frac{40,000 \times 14}{144 \times 450} = \frac{560,000}{64,800} = 8.64 \text{ in.} = 8\frac{5}{8} \text{ in.} \quad \text{Ans.}$$

(**1058**) The constant for center breaking loads for yellow pine (Table 52, Art. **1802**) is 550. Applying the rule given in Art. **1807**, we have

$$\frac{24,000 \times 16}{10 \times 550} = \frac{384,000}{5,500} = 69.82,$$

the square root of which is  $8.35 = \text{say } 8\frac{3}{8}$ , the required depth in inches of the beam.

(**1059**) Applying formula **128**, Art. **1808**, we have:

Breaking load in pounds per square inch of area =

$$\frac{5,000}{1 + \left( \frac{144^2}{12^2} \times .004 \right)} = 3,172 \text{ lb.}$$

With a factor of safety of 5, we have for the safe load per square inch,  $\frac{3,172}{5} = 634$  lb. The area of the cross-section of the pillar is  $12 \times 12 = 144$ . Hence, the safe load for the pillar is  $144 \times 634 = 91,296$  lb. Ans.

(1060) From Art. 1809 we find the safe shearing stress across the grain for long-leaf yellow pine to be 500 lb. per sq. in., and to resist a shearing stress of 30,000 lb. will require an area of  $\frac{30,000}{500} = 60$  sq. in. Ans.

(1061) From Art. 1809 we find the safe shearing stress across the grain for white oak to be 1,000 lb. per sq. in., and to sustain a shearing stress of 40,000 lb. will require an area of  $\frac{40,000}{1,000} = 40$  sq. in. Ans.

(1062) A uniform transverse safe load of 36,000 lb. is equivalent to a center load of 18,000 lb., which, with a factor of safety of 4, is equivalent to a center breaking load of 72,000 lb.  $72,000 \times 12 = 864,000$ . The constant for transverse breaking loads for spruce is 450. (Table 52, Art. 1802.)  $\frac{864,000}{450} = 1,920$ , the cube root of which is 12.4, the side dimension in inches of a square beam, which will safely bear the given transverse load. (Art. 1805.)

For tension, we find in Art. 1810 the safe working stress for ordinary bridge timber is 3,000 lb. per sq. in. The given beam has a pulling stress of 20,000 lb., and to resist this stress it will require  $\frac{20,000}{3,000} = 6.6$  sq. in. We must, accordingly, add this to the area of the beam required to sustain the transverse load alone. We determine the increased size as follows:  $\sqrt[4]{12.4^2 + 6.6} = 12.6$ ; hence, the beam is 12.6 inches square. Ans.

(1063) See Art. 1813 and Fig. 629.

(1064) The total load upon the bridge is  $6,000 \times 20 = 120,000$  lb. Of this amount the two king-rods sustain one-half, or 60,000 lb., which places upon each king-rod a load of  $\frac{60,000}{2} = 30,000$ . This, with a factor of safety of 6, would be equivalent to an ultimate or breaking load of  $30,000 \times 6 = 180,000$  lb. By reference to Table 53, Art. 1813, we

find that a rod  $2\frac{3}{4}$  in. in diameter has a breaking strain of 178,528 lb., which is a close approximation to the given stress. We would, accordingly, use a  $2\frac{3}{4}$  in. king-rod. Ans.

(1065) The king-rods support the needle-beam, and, as all the floor-beams rest upon the needle-beam, it carries half the total bridge load excepting what rests upon the tie-beams.

(1066) By trussing the needle-beam we practically reduce its span to one-half of its actual length.

(1067) See Art. 1814 and Fig. 631.

(1068) 20,000 lb. Ans.

(1069) The load per lineal foot on each truss is  $\frac{6,000}{2} = 3,000$  lb. As each rod supports half the load between itself and each adjacent support, it will support one-third of the total load of each truss. The total load of the truss is  $3,000 \times 33 = 99,000$  lb., one-third of which is  $\frac{99,000}{3} = 33,000$  lb. (See Art. 1814.) Ans.

(1070) See Art. 1815.

(1071) See Art. 1815.

(1072) See Art. 1816.

(1073) See Art. 1816.

(1074) See Art. 1816.

(1075) See Art. 1817.

(1076) See Art. 1818.

(1077) See Art. 1818.

(1078) See Art. 1819 and Fig. 636.

(1079) See Art. 1820.

(1080) See Art. 1821.

(1081) See Art. 1822.

(1082) See Art. 1823.





# DRAINAGE.

(QUESTIONS 756-848.)

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(756) See Art. 1395.

(757) (a) See Art. 1396.

(b) See Arts. 1397 and 1398.

(758) See Art. 1402.

(759) (a) See Arts. 1403 and 1404.

(b) See Art. 1405.

(760) See Art. 1406.

(761) If the duration of the storm is expressed in minutes (see formula 100, Art. 1406), Talbot's formula will become  $y = \frac{1.75 \times 60}{x' + .25 \times 60} = \frac{105}{x' + 15}$ . Then, for a storm of any number of minutes' duration, the value of the rate  $y$  of rainfall per hour may be found by substituting the proper value of  $x'$ .

$$(a) \ y = \frac{105}{25} = 4.20 \text{ in.} \quad \text{Ans.}$$

$$(b) \ y = \frac{105}{35} = 3.00 \text{ in.} \quad \text{Ans.}$$

$$(c) \ y = \frac{105}{45} = 2.33 \text{ in.} \quad \text{Ans.}$$

$$(d) \ y = \frac{105}{60} = 1.75 \text{ in.} \quad \text{Ans.}$$

When the duration of the storm is expressed in hours, formula **102** is used. Hence, for the next two results, we have:

$$(e) \ y = \frac{1.75}{1.25} = 1.40 \text{ in.} \quad \text{Ans.}$$

$$(f) \ y = \frac{1.75}{2.25} = .78 \text{ of an inch.} \quad \text{Ans.}$$

(762) If the duration of the storm is expressed in minutes, formula **105**, Art. **1409**, will become  $y = \frac{2.00 \times 60}{x' + .25 \times 60} = \frac{120}{x' + 15}$ . Then, for the rate  $y$  per hour, we shall have, for time in minutes,

$$(a) \ y = \frac{120}{25} = 4.80 \text{ in.} \quad \text{Ans.}$$

$$(b) \ y = \frac{120}{35} = 3.43 \text{ in.} \quad \text{Ans.}$$

$$(c) \ y = \frac{120}{45} = 2.67 \text{ in.} \quad \text{Ans.}$$

$$(d) \ y = \frac{120}{60} = 2.00 \text{ in.} \quad \text{Ans.}$$

For time in hours,

$$(e) \ y = \frac{2.00}{1.25} = 1.60 \text{ in.} \quad \text{Ans.}$$

$$(f) \ y = \frac{2.00}{2.25} = .89 \text{ of an inch.} \quad \text{Ans.}$$

(763) (a) The number of cubic feet per second of rain falling upon one acre is equal to  $\frac{43,560}{12 \times 60 \times 60} = \frac{121}{120}$  times the rate of the rainfall, in inches per hour. Ans.

(b) Consequently, a rate of rainfall of one inch per hour will be equal to a precipitation of  $1 \times \frac{121}{120} = 1\frac{1}{120}$  cubic feet per second per acre. Ans.

(764) The table is given below. It is like Table 29, Art. 1413, in every respect, except that the rate of rainfall is as given by formula 102 instead of formula 104. No explanation will be necessary.

Maximum Rates of Ordinary Rainfall, as Given by Talbot's Formula.

| Duration of Storm. |                   |                    | Rate of<br>Rainfall.<br>Inches<br>per<br>Hour.<br><i>y</i> | Duration of Storm. |                   |                    | Rate of<br>Rainfall.<br>Inches<br>per<br>Hour.<br><i>y</i> |
|--------------------|-------------------|--------------------|------------------------------------------------------------|--------------------|-------------------|--------------------|------------------------------------------------------------|
| Hr.<br><i>x</i>    | Min.<br><i>x'</i> | Sec.<br><i>x''</i> |                                                            | Hr.<br><i>x</i>    | Min.<br><i>x'</i> | Sec.<br><i>x''</i> |                                                            |
|                    | 2                 | 120                | 6.18                                                       |                    | 65                | 3,900              | 1.31                                                       |
|                    | 5                 | 300                | 5.25                                                       |                    | 70                | 4,200              | 1.24                                                       |
|                    | 8                 | 480                | 4.57                                                       | 1.25               | 75                | 4,500              | 1.17                                                       |
|                    | 10                | 600                | 4.20                                                       |                    | 80                | 4,800              | 1.11                                                       |
|                    | 12                | 720                | 3.89                                                       |                    | 85                | 5,100              | 1.05                                                       |
| 0.25               | 15                | 900                | 3.50                                                       | 1.50               | 90                | 5,400              | 1.00                                                       |
|                    | 18                | 1,080              | 3.18                                                       |                    | 100               | 6,000              | .91                                                        |
|                    | 20                | 1,200              | 3.00                                                       |                    | 110               | 6,600              | .84                                                        |
|                    | 22                | 1,320              | 2.84                                                       | 2.00               | 120               | 7,200              | .78                                                        |
|                    | 25                | 1,500              | 2.63                                                       |                    | 130               | 7,800              | .72                                                        |
|                    | 28                | 1,680              | 2.44                                                       |                    | 140               | 8,400              | .68                                                        |
| 0.50               | 30                | 1,800              | 2.33                                                       | 2.50               | 150               | 9,000              | .64                                                        |
|                    | 35                | 2,100              | 2.10                                                       | 2.75               | 165               | 9,900              | .58                                                        |
|                    | 40                | 2,400              | 1.91                                                       | 3.00               | 180               | 10,800             | .54                                                        |
| 0.75               | 45                | 2,700              | 1.75                                                       | 3.50               | 210               | 12,600             | .47                                                        |
|                    | 50                | 3,000              | 1.62                                                       | 4.00               | 240               | 14,400             | .41                                                        |
|                    | 55                | 3,300              | 1.50                                                       | 4.50               | 270               | 16,200             | .37                                                        |
| 1.00               | 60                | 3,600              | 1.40                                                       | 5.00               | 300               | 18,000             | .33                                                        |

(765) (See Art. 1405.) There is no relation between the maximum rate of rainfall during a storm and the total amount of rainfall given by the storm.

(766) (a) and (b) See Art. 1402.

(767) See Art. 1414.

(768) (a) See Art. 1415.

(b) As determined by Talbot's formula for the maximum rate of ordinary rainfall, the rate per hour given by a storm of one hour's duration is 1.4 inches. (See Question 764.) A rate of one inch per hour will be  $\frac{1.0}{1.4} \times 100 = 71.4$  per cent. of this rainfall. Ans.

(769) (a) See Art. 1451.

(b) A rate of 0.86 of an inch per hour will be  $\frac{.86}{1.4} \times 100 = 61.4$  per cent. of the rate given by a storm of one hour's duration, as determined by Talbot's formula for the maximum rate of ordinary rainfall. Ans.

(770) (a) See Art. 1419.

(b) See Art. 1421.

(771) See Art. 1422.

(772) The ratio of storm water to contemporary rainfall; that is, the percentage of the rainfall that will enter the sewer as storm water during a length of time equal to the duration of the storm. (See Arts. 1426, 1432, 1433, and 1434.)

(773) From 0.6 to 0.8 of the total amount of storm water given by the storm. (See Art. 1429.)

(774) From 0.56 to 0.75 of the rainfall for extreme conditions and from 0.32 to 0.42 for ordinary districts. (See Art. 1430.)

(775) (a) and (b) See Arts. 1432 and 1433.

(776) See Art. 1434.

(777) (a) This is accomplished by multiplying both numerator and denominator of the second term of formula 102 by 60. Thus,

$$y = \frac{1.75 \times 60}{x' + .25 \times 60} = \frac{105}{x' + 15}. \quad \text{Ans.}$$

(b) For time in seconds,

$$y = \frac{1.75 \times 60 \times 60}{x'' + .25 \times 60 \times 60} = \frac{6,300}{x'' + 900}. \quad \text{Ans.}$$

(c) (See formula 112, etc., Art. 1443.) Using Talbot's formula for rainfall, the storm-water flow per acre is expressed by the formula

$$F = f \times \frac{6,300}{\frac{k}{v_1 \sqrt{S}} + \frac{l}{v} + 900},$$

in which  $F$  is the flow of storm water per acre, in cubic feet per second,  $f$  is the coefficient of storm flow,  $k$  is the length in feet of the path of the surface flow from the most remote portion of the district,  $v_1$  is the velocity of the surface flow, in feet per second, for a slope of 1 per cent.,  $S$  is the average slope of the surface on the path  $k$ , expressed as a per cent.,  $l$  is the length of the sewer, in feet, from the point where the surface flow enters, down to the point under consideration, and  $v$  is the velocity of flow in the same, in feet per second.

(778) (a) When  $x = 0$ ,  $y = \frac{1.75}{.25} = 7.0$ , which is the value of  $y$  at the axis of ordinates. By using this value and the rates of rainfall obtained for Question 764, a sufficient number of points in the curve may be located so that it can be drawn through them with a sufficient degree of accuracy. The curve, as thus drawn, is the lower curve in the diagram of Fig. 72; it will require no further explanation.

(b) For time expressed in minutes, formula **105**, Art. **1409**, becomes

$$y = \frac{2.00 \times 60}{x' + .25 \times 60} = \frac{120}{x' + 15}$$

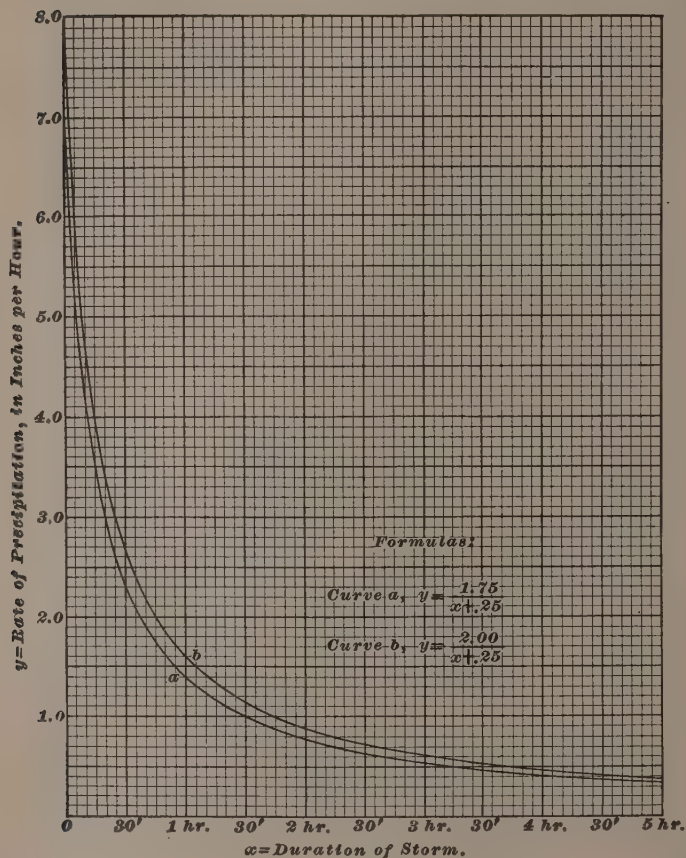


FIG. 72.

By substituting in this equation the desired values of the

time  $x$ , the corresponding values of the rate of rainfall  $y$  are obtained as follows:

| Duration of Storm. |         | Rate per Hour. |         |
|--------------------|---------|----------------|---------|
| Minutes.           | Inches. | Minutes.       | Inches. |
| 0                  | 8.00    | 90             | 1.14    |
| 2½                 | 6.86    | 100            | 1.04    |
| 5                  | 6.00    | 105            | 1.00    |
| 7½                 | 5.33    | 110            | .96     |
| 10                 | 4.80    | 120            | .89     |
| 15                 | 4.00    | 135            | .80     |
| 20                 | 3.43    | 150            | .73     |
| 25                 | 3.00    | 165            | .67     |
| 30                 | 2.67    | 180            | .61     |
| 35                 | 2.40    | 195            | .57     |
| 40                 | 2.18    | 210            | .53     |
| 45                 | 2.00    | 225            | .50     |
| 50                 | 1.85    | 240            | .47     |
| 60                 | 1.60    | 260            | .44     |
| 70                 | 1.41    | 280            | .41     |
| 80                 | 1.26    | 300            | .38     |

By taking, in each case, the duration of the storm, reduced to hours and minutes, as the abscissa, and the rate per hour as the ordinate, a sufficient number of points in the curve may be located and the curve drawn through them. The resulting curve is shown as the upper curve of the diagram, Fig. 72.

(779) (a) Formula **124**, Art. **1454**, is readily solved for any desired value of  $A$  by means of logarithms. The logarithm of 5.886, to five places, is 0.76982. Hence, this equation may be written  $\log E = \frac{1}{4} \times \log A + 0.76982$ .

If  $A = 20$ , we have  $\log E = \frac{3 \times 1.30103}{4} + 0.76982 = 1.74559$ , from which logarithm,  $E = 55.67$  cu. ft. per second. By using the value of  $A$  as the abscissa and the value of  $E$  as the ordinate, the point whose position is determined by these coordinates may be at once located. The coordi-

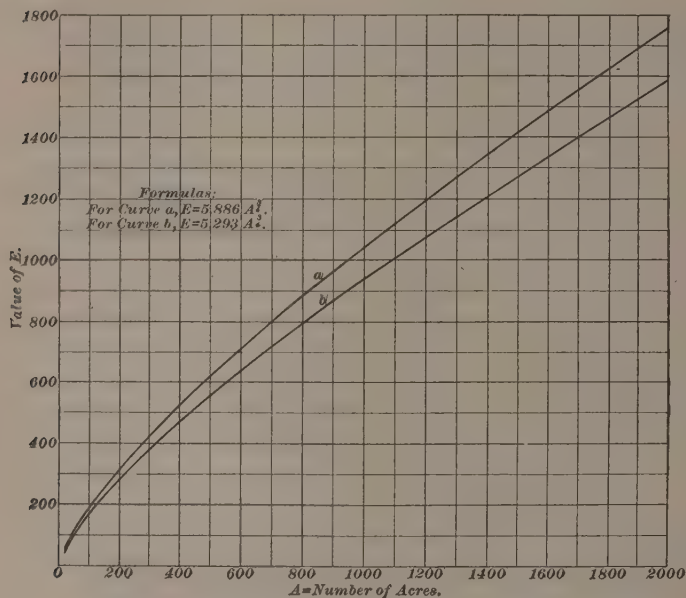


FIG. 73.

nates for a sufficient number of other points may be computed and the points located in the same manner. The curve may then be drawn through the points as thus located. The values of the coordinates, computed for the purpose of constructing this figure, are given below. The curve constructed from these coordinates is the curve marked *a*, Fig. 73.



| <i>A</i><br>Abscissas. | <i>E</i><br>Ordinates. | <i>A</i><br>Abscissas. | <i>E</i><br>Ordinates. |
|------------------------|------------------------|------------------------|------------------------|
| 20                     | 55.7                   | 600                    | 713.6                  |
| 40                     | 93.6                   | 700                    | 801.0                  |
| 60                     | 126.9                  | 800                    | 885.4                  |
| 80                     | 157.5                  | 900                    | 967.2                  |
| 100                    | 186.1                  | 1,000                  | 1,046.7                |
| 120                    | 213.4                  | 1,100                  | 1,124.3                |
| 140                    | 239.6                  | 1,200                  | 1,200.0                |
| 160                    | 264.8                  | 1,300                  | 1,274.3                |
| 180                    | 289.3                  | 1,400                  | 1,347.2                |
| 200                    | 313.0                  | 1,500                  | 1,418.7                |
| 240                    | 358.9                  | 1,600                  | 1,489.1                |
| 280                    | 402.9                  | 1,700                  | 1,558.3                |
| 320                    | 445.3                  | 1,800                  | 1,626.6                |
| 360                    | 486.5                  | 1,900                  | 1,693.9                |
| 400                    | 526.4                  | 2,000                  | 1,760.3                |
| 500                    | 622.4                  |                        |                        |

(*b*) For all values of *A* less than 60, formula **126** applies.

Hence, for  $A = 20$ ,  $E = 40$ ;  
for  $A = 40$ ,  $E = 80$ ;  
for  $A = 60$ ,  $E = 120$ .

The curve of this equation is found to be a straight line. For districts containing 60 or more acres, formula **127** applies. By means of logarithms, the values of the coordinates for a sufficient number of points are obtained from this equation; the points are then located and the curve constructed in the usual manner. The curve is marked *b* in Fig. 73. The following values are obtained for the coordinates:

| <i>A</i><br>Abcissas. | <i>E</i><br>Ordinates. | <i>A</i><br>Abcissas. | <i>E</i><br>Ordinates. |
|-----------------------|------------------------|-----------------------|------------------------|
| 60                    | 114.1                  | 700                   | 720.3                  |
| 80                    | 141.6                  | 800                   | 796.2                  |
| 100                   | 167.4                  | 900                   | 869.7                  |
| 120                   | 191.9                  | 1,000                 | 941.2                  |
| 140                   | 215.4                  | 1,100                 | 1,011.0                |
| 160                   | 238.1                  | 1,200                 | 1,079.3                |
| 180                   | 260.1                  | 1,300                 | 1,145.9                |
| 200                   | 281.5                  | 1,400                 | 1,211.4                |
| 240                   | 322.7                  | 1,500                 | 1,275.8                |
| 280                   | 362.3                  | 1,600                 | 1,339.0                |
| 320                   | 400.5                  | 1,700                 | 1,401.3                |
| 360                   | 437.5                  | 1,800                 | 1,462.7                |
| 400                   | 473.4                  | 1,900                 | 1,523.2                |
| 500                   | 559.7                  | 2,000                 | 1,583.0                |
| 600                   | 641.7                  |                       |                        |

(780) In order to obtain the value of any ordinate to the curve constructed for each assumed value of  $N$ , the logarithm of  $N$  and three times the logarithm of the value assigned to  $A$  are substituted in the equation and the equation solved; the result will be the logarithm of  $d$ . The number corresponding to this logarithm will then be the diameter of the sewer, in inches, or the ordinate to the curve for that point to which the value of  $A$  is the abscissa. No further explanation will be required. The four curves marked, respectively,  $a$ ,  $b$ ,  $c$ , and  $d$  are shown in Fig. 74.

(781) ( $a$ ) The length of the trunk sewer is 10,800 feet, and its upper end is 90 feet from the upper limit of the district. Therefore, the length of the district is  $10,800 + 90 = 10,890$  feet, and, as there are 43,560 square feet in an acre, the number of acres contained in the district is  $\frac{10,890 \times 2,000}{43,560} = 500$  acres. Ans.

(b) From Table 30, Art. **1431**, the mean value of  $f$  for class (c) is found to be .18, and from Table 31, Art. **1442**,

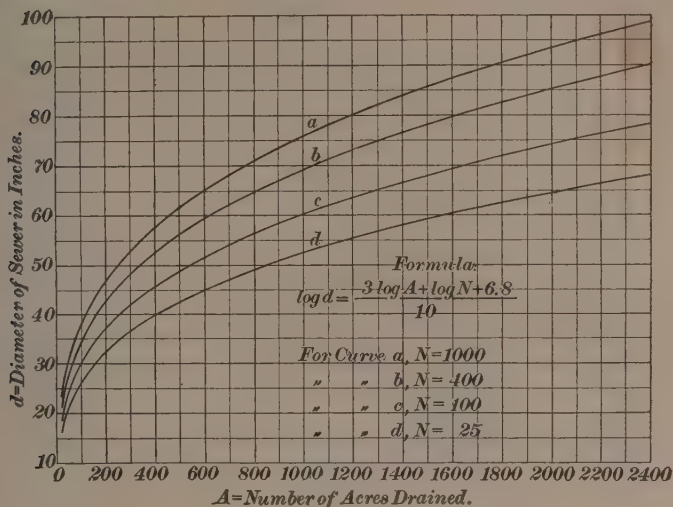


FIG. 74.

the mean value of  $v_1$  for the same class is found to be .40. Hence, by substituting the values of  $f$ ,  $v_1$ ,  $k$ ,  $l$ ,  $v$ , and  $S$  in the formula for storm-water flow per acre, as written in compliance with Question 777 (c), we get, as the flow per acre,

$$F = \frac{.18 \times 6,300}{\frac{1,000}{.40 \times \sqrt{1}} + \frac{10,800}{8} + 900} = .23874 \text{ of a cubic foot per second. Ans.}$$

(c) The total effluent per second is, therefore, equal to  $.23874 \times 500 = 119.37$  cubic feet. Ans.

(782) For a district containing 500 acres, having an average slope of 1 foot per hundred or 10 feet per thousand, the value of  $e$  (Table 33, Art. **1451**) is found to be 188.02. Hence, for the total effluent per second, we have from formula **120**,  $E = .375 \times 2.75 \times 188.02 = 193.90$  cubic feet. Ans.

(783) By substituting the values of  $f_1$ ,  $r_1$ ,  $S_1$ , and  $A$  in formula **122**, we get  $E = .75 \times 2.75 \times \sqrt[5]{10 \times 500^4}$ , from which the value of  $E$ , in cubic feet per second, is readily obtained by means of logarithms. By writing the logarithms of the respective numbers in place of the numbers, we have

$$\log E = \bar{1}.87506 + 0.43933 + \frac{1.00000 + (4 \times 2.69897)}{5} = 2.67357.$$

The number corresponding to this logarithm is 471.6, which is the number of cubic feet per second given by the formula.

Ans.

(784) From the curve for formula **124**, shown on the diagram constructed in compliance with Question 779, it is found that, for an abscissa representing 500 acres, the corresponding ordinate represents 622.4 cubic feet per second. Ans. By substituting a value of 500 for  $A$  in formula **124**, the result obtained will be 622.369 cubic feet per second, or practically the same.

(785) The effluent obtained for Question 781 is 119.37 cubic feet per second, and the velocity, as assumed in that question, is 8 feet per second. Hence, by formula **143**, Art. **1490**, the hydraulic mean radius of a circular sewer having a capacity sufficient to convey the effluent will be

$$.282 \times \sqrt[4]{\frac{119.37}{8}} = 1.089 \text{ feet. Ans.}$$

(786) (a) By reference to Fig. 368 of Art. **1482**, in which all curves have been constructed for a slope of 1 foot per hundred, which is the same as the average slope of the surface for this district, it is found that, where the abscissa to the curve for  $n = .017$  represents a value of 1.09 feet, the corresponding ordinate represents a value of about 88.0 for the coefficient  $c$ . Ans.

NOTE.—The ordinates to the curves of Fig. 368 give the values of  $c$  accurately to one unit only, though the value of the first decimal place may be approximately estimated. A small error in the decimal portion of the value of  $c$  will but slightly affect the resulting value of the velocity.

(*b*) By applying formula **131**, Art. **1478**, the velocity  $v$  is found to be  $88.0 \times \sqrt{1.09 \times .01} = 9.1875$ , or, near enough, 9.19 feet per second. Ans.

(**787**) By applying formula **144**, Art. **1491**, the approximately correct velocity  $v_o$  is found to be  $.58 \times 9.19 + .42 \times 8.00 = 8.69$  feet per second. Ans.

(**788**) (*a*) By reference to Question 781, it is found that the values of  $k$  and  $l$  are 1,000 and 10,800 feet, respectively, that  $S$  is one per cent., and that the mean values of  $f$  and  $v_i$  are .18 and .40, respectively. Hence, for the flow per acre, we have

$$F = \frac{.18 \times 6,300}{\frac{1,000}{.40 \times \sqrt{1}} + \frac{10,800}{9} + 900} = .2465 \text{ of a cubic foot per second. Ans.}$$

(*b*) As there are 500 acres in the district (see Question 781), the total estimated effluent will be  $500 \times .2465 = 123.25$  cubic feet per second. Ans.

(**789**) By applying formula **143**, Art. **1490**, we have for the required value of the hydraulic mean radius,

$$r = .282 \times \sqrt{\frac{123.25}{9}} = 1.04357, \text{ or, near enough, } 1.044 \text{ feet. Ans.}$$

(**790**) (*a*) By reference to Fig. 368 of Art. **1482**, in which all curves are for a slope of 1 foot per hundred, it is found that, where the abscissa to the curve for  $n = .017$  represents a value of 1.05, the corresponding ordinate represents a value of about 87.4 for the coefficient  $c$ . Ans.

(*b*) The corresponding velocity will be equal to  $87.4 \times \sqrt{1.05 \times .01} = 8.9558$ , or, near enough, 8.96 feet per second. Ans.

(**791**) (*a*) The hydraulic mean radius used for Question 790 is 1.05 feet. Hence, according to formula **147**, Art. **1498**, the theoretical diameter of a circular sewer having,

when running full, a hydraulic mean radius of 1.05 feet, will be  $4 \times 1.05 = 4.20$  feet. Ans.

(b) A diameter of 4.20 feet will be about  $4' 2\frac{1}{2}"$ . Hence, the practical diameter will be the nearest multiple of 2 inches above this theoretical diameter, or  $4' 4"$ . Ans.

(792) (a) The discharging capacity, in cubic feet per second, will be equal to the cross-section of the flow, in square feet, multiplied by the velocity, in feet per second. (See formula 135, Art. 1486.) Hence, at a velocity of 9 feet per second, the discharging capacity of a circular sewer having the above theoretical diameter, when running full, will be  $.7854 \times 4.20^2 \times 9 = 124.69$  cubic feet per second. Ans.

(b) With a hydraulic mean radius of 1.044 feet, when running full, the diameter of the circular sewer will be  $4 \times 1.044 = 4.176$  feet. Hence, at a velocity of 9 feet per second, the discharging capacity of the sewer will be equal to  $.7854 \times 4.176^2 \times 9 = 123.2692$ , or, near enough, 123.27 cubic feet per second. Ans.

(793) (a) There are 500 acres in the district =  $A$ . The grade of the sewer is 1 foot per hundred; consequently,  $N = 100$ . By substituting the logarithms of these values in formula 128, Art. 1456, we have

$$\log d = \frac{3 \times 2.69897 + 2.0 + 6.8}{10} = 1.68969.$$

The number of which this is the logarithm is 48.943, or, near enough, 48.94, which is the diameter of the sewer in inches. Ans.

The same value for the diameter will be given by the ordinate, corresponding to an abscissa of 500, to the curve  $c$ , constructed in compliance with Question 780, for a value of  $N = 100$ .

(b) The diameter of the sewer, in feet, will be  $\frac{48.94}{12} = 4.08$  feet, nearly. Ans.

(794) For a rainfall of  $1\frac{1}{2}$  inches per hour, the value of  $C$  in formula **130** is 3.623. (Art. **1457**.) Hence, by substituting the proper values in that formula, we have

$$\log d = \frac{2 \times 2.69897 + 2.0 - 3.623}{6} = 0.62916.$$

The number of which this is the logarithm is 4.2576, or, near enough, 4.26, which is the diameter of the sewer in feet. Ans.

(795) (a) The theoretical diameter of the circular sewer obtained for Question 792 is 4.20 feet; hence, the radius of the same will be  $\frac{4.20}{2} = 2.10$  feet. By applying formula **166**, Art. **1508**, the theoretical radius of the upper arc of an egg-shaped sewer of the new form, having a capacity, when running full, equal to that of the circular sewer, is found to be  $\frac{5}{8} \times 2.10 = 1.75$  feet. Ans.

(b) A radius of 1.75 feet will be  $1.75 \times 12 = 21$  inches. As this value is not fractional, it will be the practical value of the radius of the upper arc. Ans.

(796) By multiplying the radius of the upper arc, as obtained for the preceding question, by the constants given for the old form of cross-section, in the first five items of the table of Elements of Egg-Shaped Sewers, the following values are obtained for the dimensions of the egg-shaped sewer:

(a) Horizontal diameter  $= 2 \times 21 = 42$  inches  $= 3' 6''$ .

Ans.

(b) Vertical diameter  $= 3 \times 21 = 63$  inches  $= 5' 3''$ . Ans.

(c) Radius lower arc  $= \frac{3}{2} \times 21 = 31\frac{1}{2}$  inches  $= 0' 10\frac{1}{2}''$ . Ans.

(d) Radius side arc  $= 3 \times 21 = 63$  inches  $= 5' 3''$ . Ans.

(e) Distance between centers of upper and lower arcs  $= 1\frac{1}{2} \times 21 = 31\frac{1}{2}$  inches  $= 2' 7\frac{1}{2}''$ . Ans.

(797) This sewer has the old form of cross-section. Hence, according to item (13) of the same table its

hydraulic mean radius, when running full, will be  $1.75 \times .5793 = 1.014$  feet. Ans.

(798) (a) By reference to Fig. 368 of Art. 1482, in which all curves are for a slope of 1 foot per hundred, it is found that at the point where the abscissa to the curve for  $n = .017$  represents a value of 1.02 feet for  $r$ , the ordinate to the same point on the curve represents a value of about 87.0 for  $c$ . Ans.

(b) The computed velocity will, therefore, be  $87.0 \times \sqrt{1.02 \times .01} = 8.7866$ , or, near enough, 8.79 feet per second. Ans.

(799) (a) According to item (10) of table of Elements of Egg-Shaped Sewers, the area of the interior cross-section of this sewer will be  $1.75^2 \times 4.5941 = 14.0694$ , or, near enough, 14.07 square feet. Ans.

(b) The discharging capacity of the sewer (see formula 135, Art. 1486) will be  $8.79 \times 14.07 = 123.6753$ , or, near enough, 123.68 cubic feet per second. Ans.

(800) (a) By formula 172, Art. 1510, using radii instead of diameters, the theoretical radius of the upper arc will be  $.847 \times 2.10 = 1.7787$ , or, near enough, 1.78 feet. Ans.

(b) A radius of 1.78 feet is equal to  $1.78 \times 12 = 21\frac{3}{4}$  inches. The practical radius, taken at the next full inch above this value, will be 22 inches. Ans.

(801) By multiplying the practical value of the radius of the upper arc, as obtained for the preceding question, by the constants given for the new form of cross-section in the first five items of the table referred to in Question 799, the following dimensions are obtained:

(a) Horizontal diameter  $= 2 \times 22 = 44$  inches  $= 3' 8''$ . Ans.

(b) Vertical diameter  $= 3 \times 22 = 66$  inches  $= 5' 6''$ . Ans.

(c) Radius of lower arc  $= \frac{22}{4} = 5\frac{1}{2}$  inches  $= 0' 5\frac{1}{2}''$ . Ans.

(d) Radius of side arc  $= 2\frac{2}{3} \times 22 = 58\frac{2}{3}$  inches  $= 4' 10\frac{2}{3}''$ .  
Ans.



(c) Distance between centers of upper and lower arcs =  $1\frac{3}{4} \times 22 = 38\frac{1}{2}$  inches  $\doteq 3' 2\frac{1}{2}"$ . Ans.

(802) According to item (13) of table of Elements of Egg-Shaped Sewers, the hydraulic mean radius of an egg-shaped sewer, having the new form of cross-section, will be, when running full, equal to the radius of the upper arc, in feet, multiplied by the constant .5688. A radius of 22 inches is equal to  $1\frac{11}{16}$  feet. Hence, for this sewer the hydraulic mean radius, when running full, is  $.5688 \times 1\frac{11}{16} = 1.0428$ .  
Ans.

(803) (a) By reference to Fig. 368, Art. 1482, in which all curves are for a slope of 1 foot per hundred, it is found that, at the point where the abscissa to the curve for  $n = .017$  represents a value of 1.04 feet for  $r$ , the ordinate to the same point in the curve represents a value of about 87.3 for the coefficient  $c$ . Ans.

(b) The computed velocity will, therefore, be  $87.3 \times \sqrt{1.04 \times .01} = 8.9029$ , or, near enough, 8.90 feet per second.  
Ans.

(804) (a) According to item (10) of same table, the area of the interior cross-section of an egg-shaped sewer of the new form will be equal to the square of the radius of the upper arc in feet, multiplied by the constant 4.4602. The radius of the upper arc is 22 inches  $= 1\frac{11}{16}$  feet. Hence, the area of the interior cross-section of this sewer will be  $1\frac{11}{16} \times 1\frac{11}{16} \times 4.4602 = 14.9912$ , or, near enough, 14.99 square feet. Ans.

(b) The discharge, in cubic feet per second, will be equal to the area of the cross-section of flow, in square feet, multiplied by the velocity in feet, or  $14.99 \times 8.90 = 133.41$  cubic feet per second. Ans.

(805) (a) The total length of the district is  $10,800 + 90 = 10,890$  feet from the upper limit of the district to the outlet of the sewer, and the width of the district is 2,000 feet. (See Question 781.) Hence, the length of the district above a point 4,356 feet above the outlet of the sewer

will be  $10,890 - 4,356 = 6,534$  feet, and the number of acres in this portion of the district will be  $\frac{6,534 \times 2,000}{43,560} = 300$  acres. Ans.

(b) (See Question 781.) Using formula **111**,  $l = 10,800 - 4,356 = 6,444$ , and the flow per acre  $F$  will be

$$F = \frac{.18 \times 6,300}{\frac{1,000}{.40 \times \sqrt{1}} + \frac{6,444}{8} + 900} = .2696 \text{ cubic foot. Ans.}$$

(c) The total effluent, therefore, will be  $300 \times .2696 = 80.88$  cubic feet per second. Ans.

(806) In Question 781, the velocity is assumed to be 8 feet per second. According to formula **143**, Art. **1490**, therefore, the hydraulic mean radius of a circular sewer having sufficient capacity to discharge the effluent, as estimated for the preceding example, will be  $.282 \times \sqrt{\frac{80.88}{8}} = .897$  of a foot. Ans.

(807) (a) By reference to Fig. 368, Art. **1482**, it is found that, at the point where the abscissa to the curve for  $n = .017$  represents a value of .90 of a foot, the ordinate to the same point on the curve represents a value of about 84.7 for the coefficient  $c$ . Ans.

(b) The computed velocity will, therefore, be  $84.7 \times \sqrt{.90 \times .01} = 8.0354$ , or, near enough, 8.04 feet per second. Ans.

(808) (a) The value of the hydraulic mean radius used in the preceding question is .90 of a foot. Hence, by formula **147**, Art. **1498**, the theoretical diameter of a circular sewer having this hydraulic mean radius will be  $4 \times .90 = 3.60$  ft. Ans.

(b) A diameter of 3.60 feet will be equal to 3' 7.2". The practical diameter will be the multiple of 2 inches next above this theoretical value, or 3' 8". Ans.

(809) (a) The discharging capacity of the sewer, in cubic feet per second, is equal to the area of the cross-

section of the flow, or the interior cross-section of the sewer, when running full, in square feet, multiplied by the velocity of the flow, in feet per second. As found for Question 807, the velocity is 8.04 feet per second. The theoretical diameter obtained for the preceding question is 3.60 feet. Hence, the discharging capacity of the sewer will be  $8.04 \times .7854 \times 3.60^2 = 81.8374$ , or, near enough, 81.84 cubic feet per second.

Ans.

(b) The value of the hydraulic mean radius obtained for Question 806 is .895 of a foot, and the corresponding diameter will be  $4 \times .895 = 3.58$  feet. With this diameter, the discharging capacity of the sewer will be  $8.04 \times .7854 \times 3.58^2 = 80.9306$ , or, near enough, 80.93 cubic feet per second.

Ans.

(810) (a) The theoretical diameter of the circular sewer, as obtained for Question 808, is 3.6 feet, and, for the same, the radius is  $\frac{3.6}{2} = 1.8$  feet. Hence, by applying formula **166**, Art. **1508**, the radius of the upper arc of an egg-shaped sewer of the old form having an equal discharging capacity is  $\frac{5}{8} \times 1.8 = 1.5$  feet. Ans.

(b) A radius of 1.5 feet is equal to  $1.5 \times 12 = 18$  inches. As this dimension does not contain any fraction of an inch, it will be the practical radius of the upper arc of the sewer.

Ans.

(811) The dimensions may be obtained by multiplying the radius of the upper arc by the constants given for the old form of cross-section, in the first five items of table of Elements of Egg-Shaped Sewers, as follows:

(a) Horizontal diameter =  $2 \times 18 = 36$  inches = 3' 0".

Ans.

(b) Vertical diameter =  $3 \times 18 = 54$  inches = 4' 6". Ans.

(c) Radius of lower arc =  $\frac{18}{2} = 9$  inches = 0' 9". Ans.

(d) Radius of side arc =  $3 \times 18 = 54$  inches = 4' 6". Ans.

(e) Distance between centers of the upper and lower arcs =  $1\frac{1}{2} \times 18 = 27$  inches = 2' 3". Ans.

(812) By multiplying the radius of the upper arc, in feet, by the constant given, for the old form of cross-section, in item (13) of the same table, the hydraulic mean radius of the sewer, when running full, is found to be  $.5793 \times 1.5 = .869$  of a foot. Ans.

(813) (a) By reference to Fig. 368, Art. 1482, it is found that, at that point where the abscissa to the curve for  $n = .017$  represents a value of .87 of a foot, the ordinate to the same point in the curve represents a value of about 84.0 for the coefficient  $c$ . Ans.

(b) The computed velocity will, therefore, be  $84.0 \times \sqrt{.87 \times .01} = 7.835$ , or, near enough, 7.84 feet per second.

Ans.

(814) (a) By multiplying the square of the radius of the upper arc, in feet, by the constant given, for the old form of cross-section, in item (10) of the table used in the preceding questions, the area of the cross-section is found to be  $4.5941 \times 1.5^2 = 10.3367$ , or, near enough, 10.34 square feet. Ans.

(b) The discharging capacity of the sewer will be equal to the area of cross-section multiplied by the velocity of flow, or  $10.34 \times 7.84 = 81.0656$ , or, near enough, 81.07 cubic feet per second. Ans.

(815) (a) The entire district is of rectangular form and is 10,000 feet long and 4,356 feet wide. Hence, as there are 43,560 square feet in an acre, there are  $\frac{10,000 \times 4,356}{43,560} = 1,000$  acres in the entire district. Ans.

(b) Each sub-district is 2,178 feet long and 2,000 feet wide. Hence, it contains  $\frac{2,178 \times 2,000}{43,560} = 100$  acres. Ans.

(c) From table of Coefficients of Roughness, it is found that for pipe sewers laid under the usual conditions the proper value of  $n$ , the coefficient of roughness, is .013. Ans.

(816) From Table 30, Art. 1431, it is found that, for class (c), the mean value of  $f$ , the coefficient of storm flow,

is .30, and from Table 31, Art. **1442**, it is found that the mean value of  $v_1$  for the same class is .85. The length of the lateral sewer is 2,178 feet, and  $k$  is equal to 1,000 feet. Hence, by substituting the proper values in the formula stated in compliance with Question 777 ( $c$ ), we have for the flow per second per acre,

$$F = \frac{.30 \times 6,300}{1,000} \frac{1}{.85 \times \sqrt{.25} + \frac{2,178}{9} + 900} = .54077.$$

As there are 100 acres in each sub-district, the maximum effluent discharged into the trunk sewer by each of these two lateral sewers is  $100 \times .54077 = 54.08$  cubic feet per second. Ans.

(817) The total effluent, as estimated for the preceding question, is 54.08 cubic feet per second, and the assumed velocity is 9 feet per second. Hence, by formula **143**, Art. **1490**, the hydraulic mean radius is equal to

$$.282 \times \sqrt{\frac{54.08}{9}} = .691. \text{ Ans.}$$

(818) ( $a$ ) In Fig. 368, Art. **1482**, in which all curves are for a slope of 1 foot per hundred, where the abscissa to the curve for  $n = .013$  has a value of 0.69, the corresponding ordinate, representing the coefficient  $c$ , has a value of about 109.4. Ans.

( $b$ ) The correct slope or grade of the lateral sewer is .0081 (Question 815). The computed velocity will, therefore, be  $109.4 \times \sqrt{.69 \times .0081} = 8.1786$ , or, near enough, 8.18 feet per second. Ans.

(819) ( $a$ ) By substituting the proper values of  $n$ ,  $r$ , and  $s$  in that portion of formula **132**, Art. **1479**, relating to the value of  $c$ , we get

$$c = \frac{23 + \frac{1}{.013} + \frac{.00155}{.0081}}{.5521 + \left[ 23 + \frac{.00155}{.0081} \right] \frac{.013}{\sqrt{.69}}} = 109.27. \text{ Ans.}$$

( $b$ ) As  $c = 109.27$ ,  $r = .69$ , and  $s = .0081$ , we have for

the velocity, as given by formula **131**,  $v = 109.27 \times \sqrt{.69 \times .0081} = 8.1734$ , or, near enough, 8.17 feet per second. Ans.

(820) (a) The theoretical diameter of a circular sewer is four times the required hydraulic mean radius (formula **147**, Art. **1498**). Hence, from Questions 817 and 818, the theoretical diameter of this sewer will be  $4 \times .69 = 2.76$  feet. Ans.

(b) The practical diameter will be the nearest multiple of 2 inches above the theoretical diameter. As the theoretical diameter of 2.76 feet equals about 2 feet  $9\frac{1}{2}$  inches, the practical diameter will be 2 feet 10 inches. Ans.

(821) The hydraulic mean radius of a circular sewer flowing full is equal to one-fourth of its internal diameter (Art. **1498**). A diameter of 30 inches is equal to  $\frac{30}{12} = 2.5$  feet. Hence, the hydraulic mean radius, in feet, is  $\frac{2.5}{4} = .625$  of a foot. Ans.

(822) (a) By reference to Fig. 368, Art. **1482**, in which all curves are for a slope of 1 foot per hundred, it is found that, for an abscissa representing a value of .625 for the hydraulic mean radius, the corresponding ordinate to the curve for  $n = .013$  represents a value of about 107.4.

Ans.

(b) By substituting this value for the coefficient  $c$ , a value of .625 for  $r$ , and the correct value .0081 for the slope in formula **131**, we have  $v = 107.4 \times \sqrt{.625 \times .0081} = 7.6416$ , or, near enough, 7.64 feet per second. Ans.

(823) (a) The area of the internal cross-section of the sewer, in square feet, multiplied by the velocity, in feet per second, will give the discharge, in cubic feet per second. Hence, the discharge, in cubic feet per second, will be  $.7854 \times 2.5^2 \times 7.64 = 37.5029$ , or, near enough, 37.50 cubic feet. Ans.

(b) Likewise, at a velocity of  $7\frac{1}{2}$  feet per second, the discharge, in cubic feet per second, will be  $.7854 \times 2.5^2 \times 7\frac{1}{2} = 35.9975$ , or, near enough, 36.00 cubic feet. Ans.

(824) The lateral sewer can be laid with sewer pipe from its upper end, which is at the outer edge of the district, down to that point where the maximum effluent from that portion of the sub-district above the point will equal the discharging capacity of the 30-inch sewer pipe laid at the assumed grade. This discharging capacity is computed at 37.50 cubic feet per second, but, in order to be on the safe side, it is taken at 36 cubic feet per second. The total effluent, therefore, from that portion of the sub-district drained by the pipe sewer, must not exceed 36 cubic feet per second.

If  $y$  represents the number of acres in that portion of the sub-district drained by the pipe sewer, then the flow per acre will be  $\frac{36}{y}$ . If  $x$  represents the length of the pipe sewer, in feet, it will also represent the length of that portion of the sub-district drained by the pipe sewer. As the width of the sub-district is 2,000 feet, and there are 43,560 square feet in one acre, we may write  $y = \frac{2,000 x}{43,560} = \frac{x}{21.78}$ . Hence, for the flow per acre, we may write

$$F = \frac{36}{y} = \frac{36}{\frac{x}{21.78}} = \frac{784.08}{x}.$$

The mean values of  $f$  and  $v$ , for class (c) are .30 and .85, respectively. The average surface slope is .25 of a foot per hundred, and the value of  $k$  is 1,000 (see Questions 815 and 816). Hence, we may write

$$F = \frac{.30 \times 6,300}{\frac{1,000}{.85 \times \sqrt{.25}} + \frac{x}{7\frac{1}{2}} + 900}.$$

By equating these two values of  $F$ , we have

$$\frac{784.08}{x} = \frac{.30 \times 6,300}{\frac{1,000}{.425} + \frac{x}{7\frac{1}{2}} + 900},$$

from which  $x = 1,430.4$  feet. Ans.

(825) (c) It will be convenient to take this portion of the question first. The number of acres in this portion of the sub-district is  $\frac{2,000 \times 1,430}{43,560} = 65.6565$ , or, near enough, 65.66 acres. Ans.

(a) The estimated flow per acre will be, for this velocity,

$$F = \frac{.30 \times 6,300}{\frac{1,000}{.85 \times \sqrt{.25}} + \frac{1,430}{7.64} + 900} = .5494 \text{ of a cubic foot.}$$

Hence, the total effluent will be  $65.66 \times .5494 = 36.0736$ , or, near enough, 36.07 cubic feet. Ans.

(b) For a velocity of  $7\frac{1}{3}$  feet per second in the sewer, the estimated flow per acre will be

$$F = \frac{.30 \times 6,300}{\frac{1,000}{.85 \times \sqrt{.25}} + \frac{1,430}{7\frac{1}{3}} + 900} = .54814 \text{ of a cubic foot.}$$

Hence, the total effluent will be  $65.66 \times .54814 = 35.99$  cubic feet. Ans.

(826) The length of each sub-district, and, consequently, the length of each lateral sewer, is equal to one-half the width of the district, or  $\frac{4,356}{2} = 2,178$  feet (see Question 815). Hence, if 1,428 feet of the lateral sewer are constructed of sewer pipe, there will remain  $2,178 - 1,428 = 750$  feet to be constructed of brick. Ans.

(827) The values of  $k$  and  $l$  are 1,000 and 2,178 feet, respectively, the value of  $S$  is .25, and the mean values of  $f$  and  $v_1$  are .30 and .85, respectively (see Questions 815 and 816). Hence, the flow per acre  $F$  may be written

$$F = \frac{.30 \times 6,300}{\frac{1,000}{.85 \times \sqrt{.25}} + \frac{2,178}{7.6} + 900} = .5339 \text{ of a cubic foot.}$$

From Question 815, it is known that there are 100 acres in each sub-district, and, consequently, the maximum total effluent will be  $100 \times .5339 = 53.39$  cu. ft. Ans.



(828) By reference to table of Coefficients of Roughness, in which are given the values of  $n$ , as ordinarily used, it is found that for well-constructed brickwork a value of .015 may be used. Ans.

(829) The total effluent, as obtained for Question 827, is 53.39 cubic feet per second, and the velocity assumed in that question is 7.6 feet per second. Hence, by applying formula **143**, Art. **1490**, the hydraulic mean radius required for a circular sewer, in order to convey the effluent at the assumed velocity, is equal to  $.282 \times \sqrt[3]{\frac{53.39}{7.6}} = .7474$  of a foot. Ans.

(830) (a) By reference to Fig. 368, Art. **1482**, it is found that at the point where the abscissa to the curve for  $n = .015$  represents a value of .75 of a foot, the ordinate to the same point in the curve represents a value of about 94.2 for the coefficient  $c$ .

(b) By using this value for  $c$ , a value of .75 for  $r$ , and the correct value of .0081 for  $s$ , the computed velocity will be  $94.2 \times \sqrt[3]{.75 \times .0081} = 7.3422$ , or, near enough, 7.34 feet per second. Ans.

(831) By applying formula **147**, the theoretical inner diameter of the sewer is found to be  $4 \times .75 = 3.00$  feet. As this result contains no fraction, it will also be the practical inner diameter. Ans.

(832) The discharging capacity will be equal to  $7.34 \times .7854 \times 3^2 = 51.8835$ , or, near enough, 51.88 cubic feet per second. Ans.

(833) By applying formula **146**, the required value of the hydraulic mean radius is found to be equal to  $.75 \times \left(\frac{53.39}{51.88}\right)^{\frac{2}{3}} = 0.758656$ , or, expressed to the third decimal place, 0.759 of a foot. Ans.

(834) (a) By reference to the diagram of Fig. 368, Art. **1482**, it is found that, at the point where the abscissa

to the curve for  $n = .015$  represents a value of .76 of a foot, the ordinate to the curve at the same point represents a value of about 94.4 for the coefficient  $c$ . Ans.

(b) The computed velocity will, therefore, be equal to  $94.4 \times \sqrt{.76 \times .0081} = 7.4066$ , or, near enough, 7.41 feet per second. Ans.

(835) (a) By applying formula **147**, the theoretical diameter of this circular sewer is found to be  $4 \times .76 = 3.04$  feet. Ans.

(b) By formula **140**, the area of the cross-section is  $.7854 \times 3.04^2 = 7.2584$  square feet. Ans.

(c) By formula **135**, the discharge will be equal to  $7.41 \times 7.2584 = 53.7847$ , or, near enough, 53.78 cubic feet. Ans.

(d) A diameter of 3.04 feet is equal to 3 feet and 0.48 of an inch. The nearest multiple of 2 inches above this value will be 3 feet 2 inches, which will be the practical diameter. Ans.

(836) (a) From Question 815, the length of the trunk sewer from the point where the lateral sewers  $l_1$  and  $l'_1$  enter it, down to the point  $e_o$ , is known to be 3,000 feet. Hence, the flow per acre may be stated as follows:

$$F = \frac{.30 \times 6,300}{\frac{1,000}{.85 \times \sqrt{.25}} + \frac{1,428}{7.6} + \frac{750}{7.4} + \frac{3,000}{10}} + 900 = .4919$$

of a cubic foot per second. Ans.

(b) The point  $e_o$  is where the trunk sewer crosses the lower limits of sub-districts 2 and 2'. Consequently, the drainage from the four sub-districts 1, 1', 2, and 2' is discharged through the trunk sewer at this point (see Fig. 373, Art. **1514**). From Question 815, we know that each sub-district contains 100 acres. Hence, the drainage from 400 acres is conveyed by the trunk sewer at this point, and the total effluent will be  $400 \times .4919 = 196.76$  cubic feet per second. Ans.

(837) According to formula **143**, Art. **1490**, the required value of the hydraulic mean radius will be  $.282 \times \sqrt{\frac{196.76}{10}} = 1.251$  feet, very nearly. Ans.

(838) (a) By reference to Fig. 368, Art. **1482**, it is found that, at the point where the abscissa to the curve for  $n = .017$  represents a value of 1.25 feet for  $r$ , the ordinate to the same point in the curve represents a value of about 90.6 for the coefficient  $c$ . Ans.

(b) The computed velocity will, therefore, be  $90.6 \times \sqrt{1.25 \times .01} = 10.1294$ , or, near enough, 10.13 feet per second. Ans.

(839) The value of the hydraulic mean radius used in the preceding question is 1.25 feet. Hence, according to formula **147**, Art. **1498**, the theoretical diameter of the sewer will be  $4 \times 1.25 = 5.00$  feet. As this result contains no fraction, it will also be the practical diameter of the sewer. Ans.

(840) By formula **140**, Art. **1490**, the area of the interior cross-section of the sewer will be equal to  $.7854 \times 5^2 = 19.635$  square feet, and by formula **135**, Art. **1486**, the discharge given by the sewer will be equal to  $10.13 \times 19.635 = 198.9026$ , or, near enough, 198.90 cubic feet per second. Ans.

(841) (a) The interior radius of the circular sewer is  $\frac{1}{2} \times 5 = 2\frac{1}{2}$  feet. Hence, by formula **172**, Art. **1510**, the theoretical value of the radius of the upper arc of an egg-shaped sewer of the new form will be  $.847 \times 2.5 = 2.1175$  feet. Ans.

(b) A radius of 2.1175 feet will be equal to 25.41 inches. The practical value of the radius will be at the next full inch above the theoretical value, or 26 inches. Ans.

(842) By multiplying the practical value of the radius of the upper arc, as obtained for the preceding question, by the constants given for the new form of cross-section, in

the first five items of table of Elements of Egg-Shaped Sewers, the practical dimensions of the sewer are obtained as follows:

- (a) Horizontal diameter =  $3 \times 26 = 78$  inches =  $4' 4''$ . Ans.  
 (b) Vertical diameter =  $3 \times 26 = 78$  inches =  $6' 6''$ . Ans.  
 (c) Radius of lower arc =  $\frac{1}{2} \times 78 = 39$  inches =  $3' 3\frac{1}{2}''$ . Ans.  
 (d) Radius of side arc =  $1\frac{1}{2} \times 26 = 39\frac{1}{2}$  inches =  $3' 3\frac{1}{4}''$ . Ans.  
 (e) Distance between centers of upper and lower arcs =  $1\frac{1}{2} \times 26 = 45\frac{1}{2}$  inches =  $3' 9\frac{1}{4}''$ . Ans.

(S43) From Question 841, the theoretical value of the radius of the upper arc is known to be 2.1175 feet. Hence, by item 10 of the same table, the hydraulic mean radius of an egg-shaped sewer of the new form, having this value for the radius of the upper arc, will be, when flowing full, equal to  $.5688 \times 2.1175 = 1.204$  feet. Ans.

(S44) (a) By reference to Fig. 908, Art. 1482, it is found that, at the point where the abscissa to the curve for  $n = .11$  represents a value of 1.204 feet for  $r$ , the ordinate to the same point in the curve represents a value of about 89.9 for the coefficient  $c$ . Ans.

(b) The computed velocity will, therefore, be  $89.9 \times \sqrt{1.204 \div .01} = 2.8644$ , or, near enough, 2.86 feet per second. Ans.

(S45) (a) By multiplying the square of the (theoretical) radius of the upper arc, as obtained for Question 841, by the constant given, for the new form of cross-section, in item 10 of the table of Elements of Egg-Shaped Sewers, the area of the interior cross-section then is found to be  $4.4602 \times 2.1175^2 = 19.7886$ , or, practically, 20.00 square feet. Ans.

(b) By applying formula 135, Art. 1486, the discharge of this sewer is found to be equal to  $9.85 \times 20.00 = 197.20$  cubic feet per second. Ans.

(S46) For an egg-shaped sewer having the actual dimensions obtained for Question 842, the radius of the upper arc is 39 inches =  $3\frac{3}{4}$  feet (see Question 841). By

multiplying this by the constant given, for the new form of cr ss-section, in item (13) of table of Elements of Egg-Shaped Sewers, the hydraulic mean radius of this sewer, when running full, is found to be  $.5688 \times \frac{4}{3} = 1.232$  feet.

Ans.

(S47) (1) By reference to Fig. 368, Art. 1482, it is found that at the point in the curve for  $\pi = .017$  where the abscissa represents a value of 1.23 feet for  $r$ , the ordinate to the same point in the curve represents a value of about 90.2 for the coefficient  $c$ . Ans.

(2) The computed velocity will, therefore, be  $90.2 \times (1.23 \times .01) = 10.0036$ , or, near enough, 10.00 feet per second. Ans.

(S48) (1) By multiplying the square of the radius of the upper arc by the constant given, for the new form of cross-section, in item (10) of the table of Elements of Egg-Shaped Sewers, the area of the interior cross-section is found to be  $4.4602 \times (\frac{4}{3})^2 = 20.9381$ , or, near enough, 20.94 square feet. Ans.

(2) The discharging capacity of this sewer will, therefore, be  $10.00 \times 20.94 = 209.40$  cubic feet per second. Ans.



# SEWERAGE.

(QUESTIONS 849-955.)

(849) (a) See Art. **1526**, last sentence. (b) See Art. **1528**, first two sentences.

(850) See Art. **1532**, last sentence.

(851) (a) See Art. **1533**. (b) See Art. **1534**.

(852) See Art. **1535**.

(853) See Art. **1536**.

(854) See Art. **1537**.

(855) See Art. **1538**.

(856) See Art. **1539**.

(857) See Art. **1540**.

(858) See Art. **1541**.

(859) See Art. **1542**.

(860) See Art. **1543**.

(861) See Art. **1544**.

(862) (a) The probable future population per acre tributary to the sewer will be  $50 + .20 \times 50 = 60$ , and the total population that must be provided for as tributary to the sewer will be  $60 \times 45 = 2,700$ . Ans.

(b) The average daily consumption is assumed to be 90 gallons per day per capita. Hence, by formula **177**, Art. **1543**, the required discharge, in cubic feet per second, will be  $\frac{2,700 \times 90}{324,000} = 0.75$ . Ans.

(863) By formula **185**, Art. **1550**, the approximate diameter  $d_0$  will be equal to  $\frac{1}{4.34} \sqrt[5]{\frac{.75^3}{.0005}} = .9392$  ft. This result is obtained by logarithms as follows:

$$\begin{array}{rcl}
 \log .75 & = & \overline{1.8750613} \\
 \log .75^3 & = & \overline{1.7501226} \\
 \log .0005 & = & \overline{4.6989700} \\
 & & 5)3.0511526 \\
 \log 5\text{th root} & = & \overline{0.6102305} \\
 \log 4.34 & = & \overline{0.6374897} \\
 \log d_0 & = & \overline{1.9727408}
 \end{array}$$

from which  $d_0 = .93916$ , very closely.

(864) (a) From the approximate value  $d_0$  of the diameter, as obtained for the preceding question, the corresponding value of the hydraulic mean radius  $r$ , with the sewer flowing full, is found to be  $\frac{.9392}{4} = .2348$ , the square root of which is .4846. With this value for  $r$  and a value of  $s$  equal to .0005, the value of  $c_0$ , as given by formula **182**, Art. **1548**, will be equal to  $\frac{103.0231}{.5521 + \frac{.339}{.4846}} = 82.27$ . Ans.

(b) The square root of 82.27 is 9.0703, and, by formula **186**, Art. **1552**, the value of  $d_1$  will be  $\frac{10 \times .9392}{9.0703} = 1.0355$ . Ans.

(865) As given by formula **187**, Art. **1554**, the approximately correct diameter  $d'$  will be equal to  $\frac{1}{5} (.9392 + 4 \times 1.0355) = 1.0162$ . Ans.

(866) (a) For this diameter, the hydraulic mean radius, with sewer flowing full, will be equal to  $\frac{1.0162}{4} = .25405$ , the square root of which is .504, very closely. Hence, by



formula **182**, Art. **1548**, the value of  $c$  will be equal to

$$\frac{103.0231}{.5521 + \frac{.339}{.504}} = 84.12. \quad \text{Ans.}$$

(b) The velocity will, therefore, be equal to  $84.12 \times \sqrt{.25405 \times .0005} = 84.12 \times .504 \times .02236 = .94798$  feet per second. Ans.

(c) The area of the cross-section will be equal to  $.7854 \times 1.0162^2 = .8111$  of a square foot and, therefore, the discharge will be equal to  $.94798 \times .8111 = .7689$  of a cubic foot per second. Ans.

(867) (a) The value of the hydraulic mean radius  $r$ , with sewer flowing full, is equal to  $\frac{1.00}{4} = 0.25$ , the square root of which is 0.5. Hence, by formula **182**, the value of the coefficient  $c$  will be equal to  $\frac{103.0231}{.5521 + \frac{.339}{.500}} = 83.75. \quad \text{Ans.}$

(b) The velocity will be equal to  $83.75 \times \sqrt{.25 \times .0005} = 83.75 \times .5 \times .02236 = .9363. \quad \text{Ans.}$

(c) The area of the cross-section will be equal to  $.7854 \times 1^2 = .7854$  of a square foot, and, therefore, the discharge will be equal to  $.9363 \times .7854 = .7354$  cubic feet per second. Ans.

(868) (a) No. For a sewer of this diameter, the minimum velocity that ordinarily will prevent deposit, as given by formula **188**, Art. **1561**, is  $2.0 + \frac{6}{12} = 2.5$  feet per second. Ans.

(b) By formula **189**, the minimum velocity permissible for a sewer of this diameter is  $2.0 + \frac{3}{12} = 2.25$  feet per second. Ans.

(869) For this diameter, the sine of the slope required to give a velocity of 2.25 feet per second, as obtained approximately by formula **190**, will be equal to  $\frac{5 \times 2.25^2}{1,000 \div 12} = .00211. \quad \text{Ans.}$

(870) This formula may be written by substituting the value of  $s$  in formula **178**, Art. **1548**, and reducing. Thus,

$$c = \frac{99.9231 + \frac{.00155}{.002}}{.5521 + \left[ .299 + \frac{.00002}{.002} \right] \times \frac{1}{\sqrt{r}}} = \frac{100.6981}{.5521 + \frac{.309}{\sqrt{r}}}. \quad \text{Ans.}$$

(871) (a) With the sewer flowing full, the value of  $r$  will be  $\frac{1.00}{4} = 0.25$ , the square root of which is 0.5. By substituting this value of  $r$  in the formula for  $c$ , as obtained for the preceding question, the value of  $c$  is found to be equal to

$$\frac{100.6981}{.5521 + \frac{.309}{.5}} = 86.05. \quad \text{Ans.}$$

(b) The corresponding velocity will be equal to  $86.05 \sqrt{.25 \times .002} = 86.05 \times .5 \times .04472 = 1.9241$  feet per second. Ans.

(872) According to the rule given in Art. **1563**, the corrected value of the slope will be equal to  $.002 \times \frac{9,600}{86.05^2} = .002593$ . Ans.

(873) This formula may be written by substituting the value of  $s$  in formula **178**, Art. **1548**, and reducing. Thus,

$$c = \frac{99.9231 + \frac{.00155}{.0027}}{.5521 + \left[ .299 + \frac{.00002}{.0027} \right] \times \frac{1}{\sqrt{r}}} = \frac{100.4972}{.5521 + \frac{.3064}{\sqrt{r}}}. \quad \text{Ans.}$$

(874) (a) With the sewer flowing full, the value of  $r$  will be 0.25, the square root of which is 0.5. By substituting this value of  $r$  in the formula obtained for the preceding question, the value of  $c$  is found to be equal to

$$\frac{100.4972}{.5521 + \frac{.3064}{.5}} = 86.26. \quad \text{Ans.}$$

(b) The corresponding velocity will be equal to  $86.26 \times \sqrt{.25 \times .0027} = 86.26 \times .5 \times .05196 = 2.241$  feet per second.

Ans.

(875) The area of the sewer will be equal to  $.7854 \times 1^2 = .7854$  of a square foot. Hence, the discharge will be  $2.24 \times .7854 = 1.7593$  cubic feet per second. Ans.

(876) (a) From formula 198, Art. 1583, calling the required slope  $s_2$ , we have  $12 \times .0027 = 10 s_2$ , from which

$$s_2 = \frac{12 \times .0027}{10} = .00324. \quad \text{Ans.}$$

(b) A diameter of 10 inches is equal to .8333 of a foot. Hence, the hydraulic mean radius of a 10-inch sewer flowing full will be equal to  $\frac{.8333}{4} = .2083$ . Ans.

(877) The formula may be written by substituting the value of  $s$  in formula 178 and reducing. Thus,

$$c = \frac{99.9231 + \frac{.00155}{.0033}}{.5521 + \left[ .299 + \frac{.00002}{.0033} \right] \times \frac{1}{\sqrt{r}}} = \frac{100.3928}{.5521 + \frac{.3051}{\sqrt{r}}}. \quad \text{Ans.}$$

(878) (a) As obtained in Question 876, the value of  $r$ , for the sewer flowing full, is .2083; the square root of this is .4564. By substituting this value of  $r$  in the formula obtained for the preceding question, the value of the coefficient  $c$  is found to be

$$c = \frac{100.3928}{.5521 + \frac{.3051}{.4564}} = 82.25. \quad \text{Ans.}$$

(b) The corresponding velocity will be equal to  $82.25 \times \sqrt{.2083 \times .0033} = 82.25 \times .4564 \times .05745 = 2.1566$  feet per second. Ans.

(879) (a) The diameter is 10 inches  $= 1\frac{1}{2}$  of a foot. Consequently, the area of the cross-section will be equal to  $.7854 \times (1\frac{1}{2})^2 = .5454$  of a square foot. Ans.

(b) The discharge of this sewer will be equal to the velocity multiplied by the area of its cross-section (formula 184), or  $2.1566 \times .5454 = 1.1762$  cubic feet per second. Ans.

(880) (a) The diameter of the sewer is 8 inches  $= \frac{8}{12} = \frac{2}{3}$  of a foot. Consequently, the area of the cross-section will be equal to  $.7854 \times (\frac{2}{3})^2 = .3491$  of a square foot. Ans.

(b) The velocity in this sewer necessary to give a discharge of 0.75 of a cubic foot per second will be equal to  $\frac{.75}{.3491} = 2.1484$  feet per second.

(881) As given by formula **189**, Art. **1562**, the minimum velocity permissible for an 8-inch sewer is  $2.0 + \frac{2}{3} = 2.375$  feet per second. Ans.

(882) As given approximately by formula **190**, the slope of an 8-inch pipe sewer having this velocity will be  $\frac{5 \times 2.375^2}{1,000 \times 8} = .003525$ . Ans.

(883) The simplified formula for the coefficient may be written by substituting .0035 for  $s$  in formula **178** and reducing. Thus,

$$c = \frac{99.9231 + \frac{.00155}{.0035}}{.5521 + \left[ .299 + \frac{.00002}{.0035} \right] \times \frac{1}{\sqrt{r}}} = \frac{100.3659}{.5521 + \frac{.3047}{\sqrt{r}}} \quad \text{Ans.}$$

(884) (a) A diameter of 8 inches is equal to  $\frac{8}{12} = .6666$  of a foot. Consequently, for a circular sewer of this diameter flowing full, the hydraulic mean radius  $r$  will be equal to  $\frac{.6666}{4} = .1666$ . Ans.

(b) The square root of  $r$ , or  $\sqrt{.1666} = .4082$ . By substituting this value in the formula obtained for the preceding question, we shall have

$$c = \frac{100.3659}{.5521 + \frac{.3047}{.4082}} = 77.28. \quad \text{Ans.}$$

(885) According to the rule given in Art. **1563**, the corrected value of the slope will be equal to  $.0035 \times \frac{9,600}{77.28^2} = .005626$ . Ans.

(886) The simplified formula may be written by substituting the value .0059 for  $s$  in formula **178** and reducing. Thus,

$$c = \frac{99.9231 + \frac{.00155}{.0059}}{.5521 + \left[ .299 + \frac{.00002}{.0059} \right] \times \frac{1}{\sqrt{r}}} = \frac{100.1858}{.5521 + \frac{.3024}{\sqrt{r}}}. \quad \text{Ans.}$$

(887) (a) For an 8-inch circular sewer flowing full, the hydraulic mean radius  $r$  is .1666, the square root of which is .4082. (See Question 884.) By substituting this value for  $r$  in the simplified formula obtained for the preceding question, the value of the coefficient  $c$  is found to be

$$\frac{100.1858}{.5521 + \frac{.3024}{.4082}} = 77.49. \quad \text{Ans.}$$

(b) The velocity will, therefore, be equal to  $77.49 \times \sqrt{.1666 \times .0059} = 77.49 \times .4082 \times .07681 = 2.4295$ . Ans.

(888) In Question 880 (a), the area of the cross-section of an 8-inch sewer was found to be .3491 of a square foot. Hence, according to formula **184**, Art. **1550**, the discharge will be  $2.43 \times .3491 = .8483$  of a cubic foot per second. Ans.

(889) (a) There are 45 acres in the sewer district (Question 862) and 43,560 square feet in one acre. As the district is 450 feet wide, its length, or the length of the sewer, will be equal to  $\frac{43,560 \times 45}{450} = 4,356$  feet. Ans.

(b) There are 5,280 feet in a mile. Consequently, the sewer will be  $\frac{4,356}{5,280} = .825$  of a mile in length. Ans.

(890) According to the diagram of Fig. 375, Art. **1568**, the slope necessary to give a uniform velocity at points 0.2, 0.4, 0.6, 0.8, and 0.9 of the length of the sewer above its lower end will be, respectively, 1.16, 1.39, 1.82, 2.86, and 4.94 times the slope at the point of maximum discharge. As the slope at the latter point is .0059, there will

be for answer (*a*),  $1.16 \times .0059 = .006844$ ; for (*b*),  $1.39 \times .0059 = .008201$ ; for (*c*),  $1.82 \times .0059 = .010738$ ; for (*d*)  $2.86 \times .0059 = .016874$ ; and for (*e*),  $4.94 \times .0059 = .029146$ .

Ans.

(891) From the diagram of Fig. 375, it is found that at a distance of one-fourth the length of the sewer above its lower end, the slope necessary to give a uniform velocity, on a straight line, will be 1.2 times the slope at the point of maximum discharge, or  $1.2 \times .0059 = .00708$ . By formula **197**, Art. **1570**, the *additional* slope around the curve necessary to give a uniform velocity will be equal to  $\frac{.00708}{2} \times \left(1 + \frac{8}{20}\right) = .004956$ . Hence, the slope required on the curve, in order to maintain the velocity uniform, will be equal to  $.00708 + .004956 = .012036$ . Ans.

(892) See Art. **1572**.

(893) See Art. **1573**.

(894) See Art. **1574**.

(895) See Art. **1575**.

(896) See Art. **1576**.

(897) See Art. **1577**.

(898) See Art. **1578**.

(899) See Art. **1580**.

(900) See Art. **1581**.

(901) See Art. **1583**.

(902) See Art. **1584**.

(903) See Art. **1584**.

(904) See Art. **1585**.

(905) See Art. **1585**.

(906) See Art. **1586**.

(907) See Art. **1586**.

(908) See Art. **1586**.

- (909) See Art. **1587**.  
 (910) See Art. **1590**.  
 (911) See Art. **1590**.  
 (912) See Art. **1591**.  
 (913) See Art. **1592**.  
 (914) See Art. **1593**.  
 (915) See Art. **1594**.  
 (916) See Art. **1595**.  
 (917) See Art. **1596**.  
 (918) See Arts. **1589** and **1596**.  
 (919) See Art. **1597**.  
 (920) See Art. **1598**.  
 (921) See Art. **1598**.  
 (922) See Art. **1598**.  
 (923) (a) See Art. **1599**.

(b) By formula **199**, Art. **1599**, the required number of rings of bricks will be  $0.4 + \frac{2 \times (8 - 2)}{25} = .88 = 1$  ring. Ans.

(c) The diameter of the sewer is 2 feet = 24 inches. By formula **200**, the number of bricks required to go around a ring will be  $1.26 \times 24 = 30.24 = 30$  bricks, and, by formula **202**, the number of bricks in a length of 2,000 feet will be equal to  $1.41 \times 30 \times 2,000 = 84,600$  bricks. Ans.

(924) (a) By formula **199**, the required number of rings of bricks will be  $0.4 + \frac{3\frac{1}{2} \times (10 - 3\frac{1}{2})}{25} = 1.31 = 2$  rings. Ans.

(b) The diameter of the sewer is  $3\frac{1}{2}$  feet = 42 inches. By formula **200**, the number of bricks required to go around the inner ring will be equal to  $1.26 \times 42 = 52.92 = 53$  rings, and the number required to go around the outer ring will be  $53 + 11 = 64$  bricks. The number of bricks required for both rings, therefore, will be  $53 + 64 = 117$ , and, by formula

**202**, the number of bricks, estimated to the nearest hundred, in a length of 1,000 feet will be equal to  $1.41 \times 117 \times 1,000 = 164,970 = 165,000$ . Ans.

(925) (a) By formula **199**, the required number of rings of bricks will be equal to  $0.4 + \frac{6 \times (16 - 6)}{25} = 2.80 = 3$  rings. Ans.

(b) The diameter of the sewer is 6 feet = 72 inches. By formula **200**, the number of bricks required to go around the inner ring will be equal to  $1.26 \times 72 = 90.72 = 91$ ; the number required to go around the second ring will be  $91 + 11 = 102$ , and the number required to go around the third, or outer, ring will be  $102 + 11 = 113$ . Hence, the total number of bricks required to go around the sewer will be  $91 + 102 + 113 = 306$ , and, by formula **202**, the total number of bricks, estimated to the nearest hundred, required for this sewer in a length of 3,000 feet will be equal to  $1.41 \times 306 \times 3,000 = 1,294,380 = 1,294,400$ . Ans.

(926) (a) By formula **199**, the required number of rings of bricks will be equal to  $0.4 + \frac{4 \times (14 - 4)}{25} = 2$  rings. Ans.

(b) The horizontal diameter of the sewer is 4 feet = 48 inches. By formula **201**, the number of bricks required to go around the inner ring will be equal to  $1.58 \times 48 = 75.84 = 76$  bricks, and the number required to go around the second, or outer, ring will be equal to  $75.84 + 13.8 = 89.64 = 90$  bricks. Hence, the number required to go around both rings will be  $76 + 90 = 166$ , and, by formula **202**, the number required for the sewer in a length of 1,000 feet will be  $1.41 \times 166 \times 1,000 = 234,060 = 234,100$ . Ans.

(927) See Art. **1601**.

(928) See Art. **1602**.

(929) See Art. **1603**.

(930) See Art. **1604**.

(931) See Art. **1605**.



(932) See Art. 1605.

(933) See Art. 1606.

(934) See Art. 1607.

(935) See Art. 1608.

(936) See table of Tensile Strength of Cements.

(937) See Art. 1609.

(938) See Art. 1621.

(939) See Art. 1622.

(940) See Art. 1623.

(941) See Art. 1624.

(942) See Art. 1627.

(943) See Art. 1628.

(944) (a) See Art. 1629. (b) See Art. 1630. (c) See Art. 1631.

(945) (a) and (b) See Art. 1632. (c) See Art. 1633.

(946) See Art. 1634.

(947) See Art. 1635.

(948) (a), (b), (c), and (d) See Art. 1636.

(949) (a), (b), (c), and (d) See Art. 1636.

(950) (a) The value of  $r$  is  $\frac{.36}{4} = .09$ . Ans.

(b) The square root of  $r$  will be equal to  $\sqrt{.09} = .3$ . Ans.

(951) (a) By substituting the value obtained in the preceding example for  $r$  in formula 179, Art. 1548, which gives the value of  $c$  for a value of  $s = .1$ , we get

$$c = \frac{99.9386}{.5521 + \frac{.2992}{.3}} = 64.50. \text{ Ans.}$$

(b) By substituting the same value for  $r$  in formula 180, we get for  $s = .01$ ,  $c = \frac{100.0781}{.5521 + \frac{.301}{.3}} = 64.34. \text{ Ans.}$

(a) By substituting the same value for  $r$  in formula **181**, we get for  $s = .001$ ,  $c = \frac{101.4731}{.5521 + \frac{.347}{.3}} = 92.82$ . Ans.

(b) By substituting the same value of  $r$  in formula **182**, we get for  $s = .0005$ ,  $c = \frac{103.0231}{.5521 + \frac{.337}{.3}} = 85.35$ . Ans.

(c) By substituting the same value of  $r$  in formula **183**, we get for  $s = .0001$ ,  $c = \frac{115.4231}{.5521 + \frac{.307}{.3}} = 52.72$ . Ans.

(952) (a) The hydraulic mean radius will be equal to  $\frac{4}{4} = 1$ . Ans.

(b) The square root of  $r$  will be equal to  $\sqrt{4} = 2$ . Ans.

(953) (a) By substituting the value obtained in the preceding example for  $r$  in formula **179**, which expresses the value of  $c$  for  $s = 1$ , we get for the value of  $c$ ,  $\frac{99.9386}{.5521 + \frac{.2992}{1}} = \frac{99.9386}{.8513} = 117.39$ . Ans.

(b) By substituting the same value for  $r$  in formula **180**, we get for  $s = .01$ ,  $c = \frac{100.0781}{.5521 + \frac{.302}{1}} = \frac{100.0781}{.8541} = 117.41$ . Ans.

(c) By substituting the same value for  $r$  in formula **181**, we get for  $s = .001$ ,  $c = \frac{101.4731}{.5521 + \frac{.312}{.3}} = 119.45$ . Ans.

(d) By substituting the same value for  $r$  in formula **182**, we get for  $s = .0005$ ,  $c = \frac{103.0231}{.5521 + \frac{.307}{.3}} = 105.61$ . Ans.

(e) By substituting the same value for  $r$  in formula **183**, we get for  $s = .0001$ ,  $c = \frac{115.4231}{.5521 + \frac{.307}{.3}} = 109.71$ . Ans.

(954) (a) The value of  $r$  is  $\frac{1}{2} = 0.5$ . Ans.

(b) The square root of  $r$  will be equal to  $\sqrt{0.5} = 0.707$ . Ans.

(955) (i) By substituting the value obtained in the preceding example for  $r$  in formula **179**, which expresses the value of  $r$  for  $s = .1$ , we get  $r = \frac{80.9386}{.5521 + \frac{.2999}{1.8028}} = 130.18$ . Ans.

(ii) By substituting the same value for  $r$  in formula **180**, we get for  $s = .01$ ,  $r = \frac{100.0781}{.5521 + \frac{.301}{1.8028}} = 130.18$ . Ans.

(iii) By substituting the same value for  $r$  in formula **181**, we get for  $s = .001$ ,  $r = \frac{101.4731}{.5521 + \frac{.319}{1.8028}} = 130.19$ . Ans.

(iv) By substituting the same value for  $r$  in formula **182**, we get for  $s = .0005$ ,  $r = \frac{103.0231}{.5521 + \frac{.339}{1.8028}} = 130.2$ . Ans.

(v) By substituting the same value for  $r$  in formula **183**, we get for  $s = .0001$ ,  $r = \frac{115.4231}{.5521 + \frac{.500}{1.8028}} = 130.16$ . Ans.



# STREETS AND HIGHWAYS.

(QUESTIONS 956-1031.)

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(956) (a) By rule **I** of Art. **1653**, the rate per cent. will be equal to  $\frac{18.98 \times 100}{584} = 3.25$  per cent. Ans.

(b) By rule **II** of the same article, the total rise will be equal to  $\frac{892 \times 2.75}{100} = 24.53$  feet. Ans.

(c) By rule **III** of the same article, the horizontal distance will be equal to  $\frac{33.75 \times 100}{5.625} = 600$  feet. Ans.

(957) See Art. **1654**.

(958) See Art. **1655**.

(959) See Art. **1656**.

(960) (a) and (b) The contour map is shown one-half size in the accompanying figure (Fig. 75) with the three routes located upon it. The route  $A b c d E$  has a practically uniform grade of about 4 per cent. The route  $A m n o p E$  has a nearly uniform grade of 6 per cent. from  $A$  to  $p$ , but a much flatter grade from  $p$  to  $E$ . By means of the contour lines, both routes were located on the map in such positions as to not exceed the given rates of grade; the point where the line marking each route crosses a contour line was located with a pair of dividers at such a distance from the last contour crossed as to give approximately the elevation necessary to a uniform grade of the given rate.

(c) The route *A s r E* is simply a straight line between *A* and *E*.

(d) By stepping a pair of dividers, set by scale to some exact distance, along the first route *A b c d E*, its length

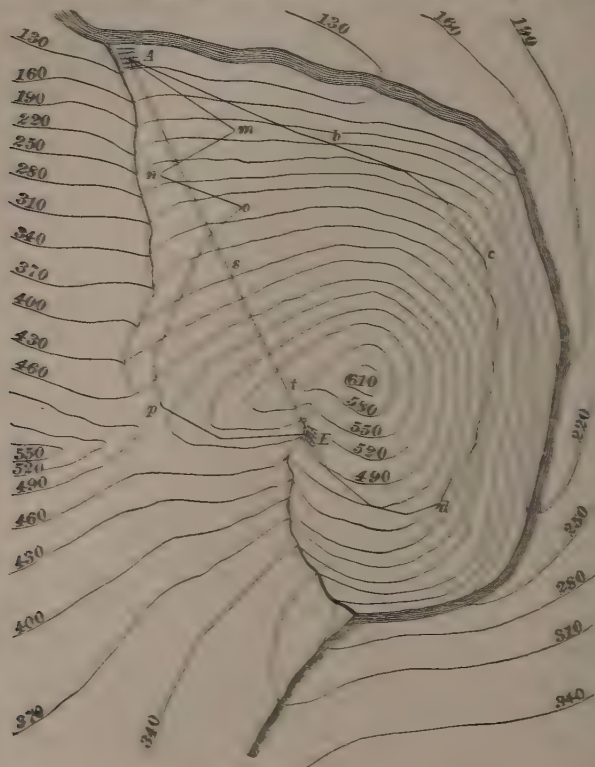


FIG. 10.

may be measured near enough for present purposes: it is found to measure nearly 9,750 feet. Ans.

(e) In the same manner, the length of the second route is found to measure about 7,850 feet. Ans.

(f) Measured by scale, the length of the third, or direct, route is found to be nearly 4,850 feet. Ans.

(961) (a) The profiles of the three routes are shown in Fig. 76, the surface lines of the respective routes being designated by the same letters as in Fig. 75. These profiles were constructed by the aid of the contour lines on the map of Fig. 75, the distances along each route being measured by scale. The highest elevation attained by the first route is the elevation of its terminus *E*, which is 505 feet. (See Question 960.) Ans.

(b) The second route attains its highest elevation at about one-third the distance from *p* to *E*; as nearly as can be estimated from the contour lines of Fig. 75, this elevation is about 510 feet. Ans.

(c) The highest elevation attained by the third, or direct, line is at *t*; as estimated from the contour lines, this elevation is about 570 feet. Ans.

(d) As shown on the profile, the third, or direct, route rises at an approximately uniform rate from an elevation of 115 feet at *A* to an elevation of about 555 feet at a distance of 4,000 feet from *A*, making a total rise of  $555 - 115 = 440$  ft. in this distance. Assuming that an approximately uniform grade can be obtained for this distance, the rate of grade is found by rule I of Art. 1653 to be about  $\frac{440 \times 100}{4,000} = 11$  per cent.

Ans.

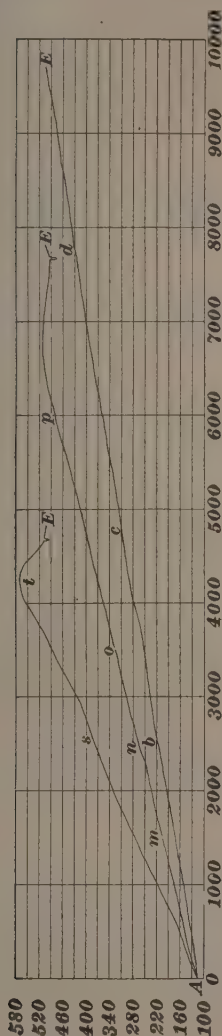


FIG. 76.

(c) The maximum grade on the third, or direct, route appears to occur between contour lines for elevations of 550 and 520 feet in descending from *t* to *E*. This descent of  $550 - 520 = 30$  ft. is made in a horizontal distance of about 150 feet, as given by scale. By rule **I** of Art. **1653**, this maximum rate of grade is about  $\frac{30 \times 100}{150} = 20$  per cent.

Ans.

(962) (a) By reference to the profile, it is seen that, in passing from the higher terminus *E* to the lower terminus *I* on the first route, no rise is encountered and no fall exceeding about 4 per cent., or no excessive fall. Consequently, the resisting length of this route will be the same as its actual length, or 9,750 feet. Ans.

(b) In passing from *E* to *I* on the second route, no falling grade steeper than about 6 per cent. is encountered, and, consequently, there is no excessive fall on this route. Between *E* and *p*, however, there is an ineffective rise of about 5 feet. By substituting this value for *r* in formula **203**, Art. **1657**, and taking the value of *c* as given for gravel roads, the resisting length of the second route is found to be equal to  $7,850 + 20 \times 5 = 7,950$  ft. Ans.

(c) On the third route, an ineffective rise of about  $570 - 505 = 65$  ft. is encountered in passing from *E* to *t*. From *t* to *I*, the horizontal distance is about 4,250 feet, and the difference of elevation is about  $570 - 115 = 455$  ft. In the same distance, a grade of 6.5 per cent. would give a total fall of  $\frac{6.5 \times 4,250}{100} = 276.25$  ft. Hence, the total excessive fall along this distance will be equal to  $455 - 276.25 = 178.75$  ft., which, added to the ineffective rise, gives  $65 + 178.75 = 243.75$  ft. as the total ineffective rise and excessive fall. By substituting this value for *r* in formula **203**, and using the value of *c* as given for gravel roads, the resisting length of this route is found to be equal to  $4,850 + 20 \times 243.75 = 9,725$  feet. Ans.



(963) The actual lengths, resisting lengths, and maximum grades for the three routes are shown below assembled in tabular form for comparison:

| <i>No. of Segments</i> | <i>Route</i>       | <i>Actual Length</i> | <i>Resisting Length</i> | <i>Maximum Grade</i> |
|------------------------|--------------------|----------------------|-------------------------|----------------------|
|                        |                    | <i>Feet.</i>         | <i>Feet.</i>            | <i>Per Cent.</i>     |
| 1                      | <i>A b c d E</i>   | 9,750                | 9,750                   | 4                    |
| 2                      | <i>A m n o p E</i> | 7,850                | 7,950                   | 6                    |
| 3                      | <i>A s t E</i>     | 3,850                | 8,725                   | 20                   |

(964) (a) See Art. 1665.

(b) and (c) See Art. 1666.

(965) See Art. 1669.

(966) (a) See Art. 1671.

(b), (c), and (d) See Art. 1672.

(967) See Arts. 1673 and 1674.

(968) See Art. 1676.

(969) (a) See Art. 1677.

(b), (c), and (d) See Art. 1678.

(970) By substituting in formula 204, Art. 1679, the values 1.00 and 1.0 for *A* and *r*, respectively, the required area of the waterway is found to be  $1.0 \times \sqrt{1.00} = 1.0$  square feet. Ans.

(971) By substituting in formula 204, the values 100 and 4.0 for *A* and *r*, respectively, the required area of the waterway is found to be  $4.0 \times \sqrt{100} = 40$  square feet. Ans.

(972) (a) See Art. 1680.

(b), (c), (d), and (e) See Art. 1681.

(973) See Art. 1682.

(974) See Art. 1683.

(975) (a) See Art. 1684.

(b) See Art. 1685.

(976) See Art. **1685**.

(977) See Art. **1686**.

(978) See Art. **1687**.

(979) See Art. **1689**.

(980) See Art. **1690**.

(981) See Art. **1691**.

(982) (a) and (b) See Art. **1692**.

(c), (d), and (e) See Art. **1693**.

(983) See Art. **1694**.

(984) (a), (b), (c), and (d) See Art. **1695**.

(e) See Art. **1696**.

(985) See Art. **1697**.

(986) (a) and (b) See Art. **1698**.

(c) According to the rule stated in Art. **1698**, the width of the tires on a four-wheeled wagon intended to carry loads of 9,000 pounds should be  $\frac{9,000}{1,200} = 7\frac{1}{2}$  inches. Ans.

(d) A load of  $1\frac{1}{2}$  tons is equal to  $1.5 \times 2,000 = 3,000$  lb. According to the rule stated in Art. **1698**, the width of the tires on a two-wheeled cart carrying a load of 3,000 pounds should be  $\frac{3,000}{2 \times 300} = 5$  inches. Ans.

(987) See Arts. **1700** and **1701**.

(988) (a), (b), and (c) See Art. **1702**.

(d) and (e) See Art. **1703**.

(989) See Art. **1703**.

(990) See Art. **1704**.

(991) See Art. **1705**.

(992) See Art. **1706**.

(993) (a), (b), and (c) See Art. **1707**.

(d) See Art. **1708**.

(994) (*a*), (*b*), (*c*), and (*d*) See Art. **1711**.

(*e*) and (*f*) See Art. **1712**.

(995) See Art. **1713**.

(996) (*a*) and (*b*) See Art. **1714**.

(*c*) See Art. **1715**.

(997) See Art. **1718**.

(998) See Art. **1719**.

(999) (*a*) and (*b*) See Art. **1720**.

(*c*), (*d*), and (*e*) See Art. **1721**.

(1000) (*a*) By substituting the width of roadway and per cent. of grade in formula **205**, Art. **1722**, and using the value of *q* for common earth roadways, as given in the table of Coefficients for Roadway Crowns, the required amount of crown is found to be equal to

$$16 \left( \frac{1}{40} + \frac{5 \left( \frac{70}{40} - 1 \right)}{800} \right) = .475 \text{ of a foot. Ans.}$$

(*b*) By substituting in formula **205** the value *q* as given in the same table for ordinary gravel roadways, and retaining the same width and grade as in (*a*), the required amount of crown is found to be equal to

$$16 \left( \frac{1}{50} + \frac{5 \left( \frac{70}{50} - 1 \right)}{800} \right) = .360 \text{ of a foot. Ans.}$$

(*c*) By substituting the width and rate of grade in formula **205**, and retaining the value *q* for gravel roadways, the required amount of crown is found to be equal to

$$20 \left( \frac{1}{50} + \frac{4 \left( \frac{70}{50} - 1 \right)}{800} \right) = .440 \text{ of a foot. Ans.}$$

(1001) (*a*) By substituting in formula **205** the width of roadway, the per cent. of grade, and the value of *q* as given in the table for wooden-block pavement, the required amount of crown is found to be equal to

$$28 \left( \frac{1}{70} + \frac{3 \left( \frac{70}{70} - 1 \right)}{800} \right) = .400 \text{ of a foot. Ans.}$$

(b) By substituting the amount of crown, width of roadway, and value of the abscissa, for  $c$ ,  $w$ , and  $x$ , respectively, in formula **206**, the value of the ordinate to the surface line of the cross-section at a distance of 3.5 feet from the center is

$$\frac{4 \times .40 \times 3.5^2}{28^2} = .025 \text{ of a foot. Ans.}$$

(c) In like manner, the ordinate to the surface line of the cross-section at a point distant 7.0 feet from the center is

$$\frac{4 \times .40 \times 7.0^2}{28^2} = .100 \text{ of a foot. Ans.}$$

(d) Likewise, the ordinate at a point distant 10.5 feet from the center is

$$\frac{4 \times .40 \times 10.5^2}{28^2} = .225 \text{ of a foot. Ans.}$$

(1002) (a) By substituting in formula **205** the width of roadway, the per cent. of grade, and the value of  $q$  as given in the table of Coefficients for Roadway Crowns, for well-laid brick pavement, the required amount of crown is found to be equal to

$$\frac{40}{100} + \frac{40 \times 2 \times (\frac{7.0}{100} - 1)}{800} = .37 \text{ of a foot. Ans.}$$

(b) By substituting in formula **207** the amount of crown, width of roadway, and length of central curve, the rate of lateral slope for the uniformly sloping portion of the roadway surface is found to be

$$\frac{4 \times .37}{2 \times 40 - 6} = .02. \text{ Ans.}$$

(c) A distance of 3 feet from the center will be at the tangent point  $t$ , where the curving portion of the cross-section joins the uniformly sloping portion. By substituting the value of the slope and the length of the central curve in formula **209**, the ordinate to the surface line of the cross-section at this point is found to be

$$\frac{.02 \times 6}{4} = .03 \text{ of a foot. Ans.}$$

(*d*) By substituting in formula **210** the value of the slope, the length of the central curve, and the abscissa, the ordinate to the surface line of the cross-section at a point distant 5 feet from the center is found to be equal to

$$.02 \times (5 - \frac{5}{4}) = .07 \text{ of a foot. Ans.}$$

(*c*) In like manner, the ordinate at a point distant 10 feet from the center is found to be

$$.02 \times (10 - \frac{5}{4}) = .17 \text{ of a foot. Ans.}$$

(*f*) Likewise, the ordinate at a point distant 15 feet from the center is found to be

$$.02 \times (15 - \frac{5}{4}) = .27 \text{ of a foot. Ans.}$$

(**1003**) (*a*) By substituting in formula **205** the width of roadway, per cent. of grade, and value of *q* as given in the table for first-class asphalt pavement, the required amount of crown is found to be

$$48 \left[ \frac{1}{120} + \frac{1.6 (\frac{70}{120} - 1)}{800} \right] = .36 \text{ of a foot. Ans.}$$

(*b*) By substituting the amount of crown, width of roadway, and length of central curve in formula **207**, the rate of the lateral slope on the uniformly sloping portion of the roadway is found to be

$$\frac{4 \times .36}{2 \times 48 - 6} = .016. \text{ Ans.}$$

(*c*) By substituting the rate of slope, length of central curve, and the abscissa in formula **210**, the ordinate to the surface line at a point distant 3 feet from the center is found to be

$$.016 \times (3 - \frac{5}{4}) = .024 \text{ of a foot. Ans.}$$

(*d*) In like manner, the ordinate to the surface line at a point distant 6 feet from the center is found to be

$$.016 \times (6 - \frac{5}{4}) = .072 \text{ of a foot. Ans.}$$

(*c*) In like manner, also, the ordinate to the surface line at a point distant 12 feet from the center is found to be

$$.016 \times (12 - \frac{5}{4}) = .168 \text{ of a foot. Ans.}$$

(f) Likewise, the ordinate to the surface line at a point distant 18 feet from the center is found to be

$$.016 \times (18 - \frac{9}{4}) = .264 \text{ of a foot. Ans.}$$

(1004) (a) By substituting in formula **205** the width of roadway, per cent. of grade, and the value of  $q$  as given in the table for granite-block pavement, the required amount of crown is found to be equal to

$$36 \left[ \frac{1}{96} + \frac{1 \times (\frac{70}{80} - 1)}{800} \right] = .39 \text{ of a foot. Ans.}$$

(b) By substituting in formula **206** the amount of crown, width of roadway, and the value of the abscissa  $x$ , the ordinate to the surface line at a point 6 feet from the center is found to be

$$\frac{4 \times .39 \times 6^2}{36^2} = .0433 \text{ of a foot. Ans.}$$

(c) In like manner the ordinate to the surface line at a point distant 9 feet from the center is found to be

$$\frac{4 \times .39 \times 9^2}{36^2} = .0975 \text{ of a foot. Ans.}$$

(d) In like manner, also, the ordinate to the surface line at a point distant 12 feet from the center is found to be

$$\frac{4 \times .39 \times 12^2}{36^2} = .1733 \text{ of a foot. Ans.}$$

(e) In like manner, also, the ordinate to the surface line at a point distant 15 feet from the center is found to be

$$\frac{4 \times .39 \times 15^2}{36^2} = .2708 \text{ of a foot. Ans.}$$

(f) In like manner, the ordinate to the surface line at a point distant 18 feet from the center is found to be

$$\frac{4 \times .39 \times 18^2}{36^2} = .39 \text{ of a foot. Ans.}$$

This ordinate is at the extreme edge of the roadway and must, of course, be equal to the crown.

(1005) (a) By substituting in formula **205** the width of roadway, per cent. of grade, and value of  $q$ , as given in

the table for cobblestone pavements, the required amount of crown is found to be equal to

$$40 \left[ \frac{1}{80} + \frac{4 \left( \frac{70}{80} - 1 \right)}{800} \right] = .475 \text{ of a foot. Ans.}$$

(b) By applying formula **207**, the rate of slope on the uniformly sloping portion of the cross-section is found to be equal to

$$\frac{4 \times .475}{2 \times 40 - 5} = .025\frac{1}{8}. \text{ Ans.}$$

(c) The ordinate to the surface line of the cross-section at a point 2.5 feet distant from the center, as given by formula **209**, is

$$\frac{.025\frac{1}{8} \times 5}{4} = .0317 \text{ of a foot (nearly). Ans.}$$

(d) The ordinate to the surface line of the cross-section at a point 5 feet distant from the center, will be given by formula **210**; it is found to be

$$.025\frac{1}{8} \times \left( 5 - \frac{5}{4} \right) = .095 \text{ of a foot. Ans.}$$

(e) The ordinate to the surface line of the cross-section at a point 10 feet distant from the center, as given by formula **210**, is

$$.025\frac{1}{8} \times \left( 10 - \frac{5}{4} \right) = .2217 \text{ of a foot (nearly). Ans.}$$

(f) In like manner, the ordinate to the surface line of the cross-section at a point distant 15 feet from the center will be

$$.025\frac{1}{8} \times \left( 15 - \frac{5}{4} \right) = .3483 \text{ of a foot. Ans.}$$

(g) Likewise, the ordinate to the surface line of the cross-section at a point distant 20 feet from the center (i. e., at the edge of the roadway) will be

$$.025\frac{1}{8} \times \left( 20 - \frac{5}{4} \right) = .475 \text{ of a foot. Ans.}$$

(1006) (a) As given by formula **205**, the amount of crown is equal to

$$48 \left[ \frac{1}{120} + \frac{1 \left( \frac{70}{120} - 1 \right)}{800} \right] = .375 \text{ of a foot. Ans.}$$

(b) The rate of slope, as given by formula **207**, is equal to

$$\frac{4 \times .375}{2 \times 48 - 5} = \frac{3}{182}.$$

The ordinate to the surface line of the cross-section at a point 2.5 feet from the center, as given by formula **209**, is

$$\frac{3}{182} \times \frac{5}{4} = .0206 \text{ of a foot. Ans.}$$

(c) By applying formula **210**, the ordinate to the surface line of the cross-section, at a point distant 6 feet from the center, is found to be

$$\frac{3}{182} \times (6 - \frac{5}{4}) = .0783 \text{ of a foot. Ans.}$$

(d) The ordinate to the surface line of the cross-section, at a distance of 12 feet from the center, as given by formula **210**, is

$$\frac{3}{182} \times (12 \times \frac{5}{4}) = .1772 \text{ of a foot. Ans.}$$

(e) In like manner, the ordinate to the surface line of the cross-section, at a point distant 18 feet from the center, is found to be

$$\frac{3}{182} \times (18 - \frac{5}{4}) = .2761 \text{ of a foot. Ans.}$$

(f) The width of gutter will be equal to twice the amount of crown, or  $2 \times .375 = .75$  of a foot. The edge of the gutter will, therefore, be at a distance of one-half the width of the roadway, less the width of the gutter, or  $\frac{48}{2} - .75 = 23.25$  ft. from the center of the roadway. The ordinate at this point will be equal to

$$\frac{3}{182} \times (23.25 - \frac{5}{4}) = .3626 \text{ of a foot. Ans.}$$

**(1007)** (a) See Art. **1731**.

(b) and (c) See Art. **1732**.

**(1008)** (a) and (b) See Art. **1734**.

(c), (d), (e), (f), and (g) See Art. **1735**.

**(1009)** See Art. **1736**.

**(1010)** (See Art. **1736**.) The edge of the sidewalk adjacent to the curb has the same elevation as the curb, which, in a street having a symmetrical cross-section, will



generally be the same as the street grade, or, in this case, 124.62 feet. If the sidewalk is 12 feet wide and has a lateral slope of 2 per cent., the elevation of the edge adjacent to the building line will be

$$124.62 + \frac{2.00 \times 12}{100} = 124.86 \text{ feet. Ans.}$$

(1011) See Art. 1737.

(1012) (a) (See Fig. 422, Art. 1738.) As both streets have a rising grade towards the curb angle  $a$ , its elevation, as estimated by the grade line of either street, will be at a distance above the center of intersection equal to the rise of the grade line in half the width of the street, or  $3 \times 20 \times .01 = .60$  of a foot. As this amount of rise will occur in each street, the difference in the elevation of this curb angle, as estimated from the two grade lines, will be zero.

Ans.

(b) Likewise, as both streets have a falling grade towards the curb angle  $b$  at the same rate and through the same distance, the difference in the elevation of the curb angle, as estimated from the two grade lines, will also be zero. Ans.

(c) From the center of intersection to a point opposite the curb angle  $c$  the grade line of the street  $AB$  falls the amount  $3 \times 20 \times .01 = .60$  of a foot, and the grade line of the street  $CD$  rises the same amount. Hence, the difference in the elevation of this curb angle, as estimated from the two grade lines, will be equal to  $.60 + .60 = 1.20$  feet.

Ans.

(d) Likewise, from the center of intersection to a point opposite the curb angle  $d$ , the grade line of the street  $AB$  rises .60 of a foot and that of  $CD$  falls the same amount. Hence, the difference in the elevation of this curb angle also, as estimated from the two grade lines, will be equal to  $.60 + .60 = 1.20$  feet. Ans.

(1013) See Art. 1739.

(1014) (a) (See Fig. 422, Art. 1738.) On each street there is a rising grade of 3 per cent. towards the curb

angle  $a$ , making the elevation of the curb angle, as given by both grade lines, equal to  $104.24 + 3 \times 20 \times .01 = 104.84$  feet. Ans.

( $b$ ) On each street the grade line falls towards the curb angle  $b$  at a rate of 3 per cent., making the elevation of the curb angle, as given by each grade line, equal to  $104.24 - 3 \times 20 \times .01 = 103.64$  feet. Ans.

( $c$ ) On the street  $AB$  the grade is descending from  $o$  towards  $B$ , giving for the curb angle  $c$  the elevation  $104.24 - 3 \times 20 \times .01 = 103.64$  ft., while on the street  $BC$  the grade is ascending from  $o$  towards  $C$ , giving for the curb angle  $c$  the elevation  $104.24 + 3 \times 20 \times .01 = 104.84$  ft. The mean of these elevations will be

$$\frac{103.64 + 104.84}{2} = 104.24 \text{ feet. Ans.}$$

( $d$ ) The elevation of the curb angle  $d$ , as determined from the grade of the street  $AB$ , is  $104.24 + 3 \times 20 \times .01 = 104.84$  ft., and as determined from the street  $CD$  it is  $104.24 - 3 \times 20 \times .01 = 103.64$  ft. The mean of these elevations is

$$\frac{104.84 + 103.64}{2} = 104.24 \text{ feet. Ans.}$$

**(1015)** See Art. 1740.

**(1016)** ( $a$ ) As the elevation of the intersection  $o$  is 137.55 feet, the distance between  $o$  and  $o'$  is 540 feet, and the grade is 2.25 per cent., the elevation of  $o'$  will be  $137.55 - 2.25 \times 540 \times .01 = 125.40$  feet. Ans.

( $b$ ) As the point  $o$  is at the center of both intersecting streets and all roadways are 40 feet wide, the distance  $o-b$  is 20 feet. Hence, the elevation of the point  $b$  is  $137.55 - 2.25 \times 20 \times .01 = 137.10$  feet. Ans.

( $c$ ) As computed by the grade of the street  $CD$ , the elevation of the curb angle  $c$  is  $137.55 + 4.25 \times 20 \times .01 = 138.40$  ft. The proper elevation of the curb angle will be a mean between this elevation and the elevation as computed by the grade line of the street  $AB$ , or

$$\frac{138.40 + 137.10}{2} = 137.75 \text{ feet. Ans.}$$

(*d*) The elevation of the curb angle *d*, as computed by the grade line of the street *CD*, is  $137.55 - 4.25 \times 20 \times .01 = 136.70$  ft. Consequently, the proper elevation of this curb angle will be

$$\frac{136.70 + 137.10}{2} = 136.90 \text{ feet. Ans.}$$

(*c*) The elevation of the point *o'*, as found above, is 125.40 feet. The elevation of the curb angle *c*, as computed by the grade of the street *AB*, is  $125.40 + 2.25 \times 20 \times .01 = 125.85$  ft.; as computed by the grade of the street *EF*, it is  $125.40 + 5.75 \times 20 \times .01 = 126.55$  ft. Hence, the proper elevation of this curb angle is

$$\frac{125.85 + 126.55}{2} = 126.20 \text{ feet. Ans.}$$

(*f*) The elevation of the curb angle *f*, as computed by the grade of the street *AB*, is 125.85 feet, as found above (*c*). As computed by the grade of the street *EF*, it is  $125.40 - 5.75 \times 20 \times .01 = 124.25$  ft. Hence, the proper elevation of this curb angle is

$$\frac{125.85 + 124.25}{2} = 125.05 \text{ feet. Ans.}$$

(*g*) The difference in the elevations obtained above for the curb angles *c* and *f* is equal to  $137.75 - 125.05 = 12.70$  ft. Their distance apart is  $540 - 20 - 20 = 500$  ft. Hence, the rate of a uniform grade between these curb angles will be equal to

$$\frac{12.70 \times 100}{500} = 2.54 \text{ per cent. Ans.}$$

(*h*) Likewise, the difference of elevation between the curb angles *d* and *c* will be  $136.90 - 126.20 = 10.70$  ft., and the rate of uniform grade between them will be

$$\frac{10.70 \times 100}{500} = 2.14 \text{ per cent. Ans.}$$

(1017) See Art. 1741.

(1018) (a) By reference to Question 1016, it is found that the width of each street is 80 feet, the width of each roadway is 40 feet, the elevation of the center of intersection  $o$  is 137.55, the elevation of  $o'$  is 125.40, and the distance between  $o$  and  $o'$  is 540 feet. The difference of elevation, or total fall, from  $o$  to  $o'$  is, therefore,  $137.55 - 125.40 = 12.15$  ft. If each intersection is made level between property lines, this difference of elevation must be made by the grade line wholly between the property lines of the block, a distance of  $540 - 40 - 40 = 460$  ft. By rule I of Art. 1653, the rate per cent. will be

$$\frac{12.15 \times 100}{460} = 2.6413 \text{ per cent., very closely. Ans.}$$

(b) If the intersections are made level between curb lines only, the difference of elevation will be made in a distance of  $540 - 20 - 20 = 500$  ft., and the rate of grade will be

$$\frac{12.15 \times 100}{500} = 2.43 \text{ per cent. Ans.}$$

(1019) (a) and (b) See Art. 1742.

(c) and (d) See Art. 1743.

(1020) (a) By reference to Question 1002, it is found that the width of roadway is 40 feet. By rule II of Art. 1653, the difference in the elevations of the curbs will be

$$\frac{40 \times 1.00}{100} = .40 \text{ of a foot. Ans.}$$

(b) From Question 1002 (b), the rate of slope on the uniformly sloping portion of the roadway surface is known to be .02 per foot. Hence, by formula 211, Art. 1744, the required eccentricity is

$$\frac{.40}{2 \times .02} = 10 \text{ feet. Ans.}$$

(c) The length of the central curve is 6 feet. By applying formula 212, same article, the value  $d_m$ , the greatest difference between the elevations of the curbs to which the formula for eccentricity will correctly apply, is found to be

$.02 \times (40 - 6) = .68$  of a foot. As the actual difference (1 foot) between the elevations of the curbs is greater than this, the formula for eccentricity of crown will not apply correctly. Ans.

(*d*) As given by formula **213**, Art. **1745**, the rate of uniform slope across the roadway will be

$$\frac{1.00}{40} = .025. \quad \text{Ans.}$$

(**1021**) (*a*) By reference to Question 1003, it is found that the width of roadway is 48 feet, the length of the central curve is 6 feet, and the rate of slope for the uniformly sloping portion of the roadway [Ans. (*b*)] is .016 per foot. Hence, from formula **212**, the greatest difference between the elevations of the curbs to which the formula for eccentricity will correctly apply is

$$.016 \times (48 - 6) = .672 \text{ of a foot.} \quad \text{Ans.}$$

(*b*) From formula **211**, the eccentricity of crown necessary to give a difference of .672 of a foot between the elevations of the curbs is found to be

$$\frac{.672}{2 \times .016} = 21 \text{ feet.} \quad \text{Ans.}$$

(*c*) From formula **211**, the eccentricity of crown necessary to give a difference of .60 of a foot between the elevations of the curbs is found to be

$$\frac{.60}{2 \times .016} = 18.75 \text{ feet.} \quad \text{Ans.}$$

(*d*) By rule **I** of Art. **1653**, the rate per cent. of the grade of the intersecting street will be

$$\frac{.60 \times 100}{48} = 1.25 \text{ per cent.} \quad \text{Ans.}$$

(**1022**) By reference to answers (*c*), (*d*), (*e*), (*f*), (*g*), and (*h*) of Question 1016, it is found that the elevations of the curb angles *c*, *d*, *e*, and *f* are 137.75, 136.90, 126.20, and 125.05 feet, respectively, and also that the rates of grade

of the curbs  $cf$  and  $de$  are  $-2.54$  per cent. and  $-2.14$  per cent., respectively.

( $c'$ ) The elevation of the curb at the point  $c_1$  will be  $137.75 - 2.54 \times 20 \times .01 = 137.242$  ft. Hence, by formula **214**, Art. **1747**, the elevation of the block corner  $c'$  will be

$$\frac{137.242 + 138.60 + .02 \times (20 + 20)}{2} = 138.321 \text{ feet. Ans.}$$

( $d'$ ) The elevation of the curb at the point  $d_1$  will be  $136.90 - 2.14 \times 20 \times .01 = 136.472$  ft. Hence, by formula **214**, the elevation of the block corner  $d'$  will be

$$\frac{136.472 + 136.05 + .02 \times (20 + 20)}{2} = 136.661 \text{ feet. Ans.}$$

( $e'$ ) The elevation of the curb at the point  $e_1$  will be  $126.20 + 2.14 \times 20 \times .01 = 126.628$  ft. Hence, by formula **214**, Art. **1747**, the elevation of the block corner  $e'$  will be

$$\frac{126.628 + 127.35 + .02 \times (20 + 20)}{2} = 127.389 \text{ feet. Ans.}$$

( $f'$ ) The elevation of the curb at the point  $f_1$  will be  $125.05 + 2.54 \times 20 \times .01 = 125.558$  ft. Hence, by formula **214**, the elevation of the block corner  $f'$  will be

$$\frac{125.558 + 123.90 + .02 \times (20 + 20)}{2} = 125.129 \text{ feet. Ans.}$$

(**1023**) ( $a$ ) See Art. **1750**

( $b$ ) and ( $c$ ) See Art. **1751**.

( $d$ ), ( $e$ ), and ( $f$ ) See Art. **1752**.

(**1024**) See Art. **1753**.

(**1025**) See Art. **1754**.

(**1026**) ( $a$ ) The record of the grade is given on the following page. It will require no explanation. The various elevations can be easily computed from the grades and distances.

## GRADE OF Ninth Avenue FROM Center of A Street TO Center of D Street.

| Station. | Left Curb. |        |                | Roadway.   |        |                | Right Curb. |        |                | Remarks.                    |
|----------|------------|--------|----------------|------------|--------|----------------|-------------|--------|----------------|-----------------------------|
|          | Elevation. |        | Rate of Grade. | Elevation. |        | Rate of Grade. | Elevation.  |        | Rate of Grade. |                             |
|          | Surface    | Grade. |                | Surface.   | Grade. |                | Surface.    | Grade. |                |                             |
| 0        |            |        |                | 218.64     |        | 0.0            |             |        |                | Center <i>A</i> street.     |
| + 15     |            |        |                | 218.64     |        | X              |             |        |                | North Curb <i>A</i> street. |
| 1        |            |        |                | 220.68     |        |                |             |        |                |                             |
| 2        |            |        |                | 223.08     |        | + 2.40         |             |        |                |                             |
| + 95     |            |        |                | 225.36     |        | X              |             |        |                |                             |
| 3        |            |        |                | 225.36     |        |                |             |        |                | South Curb <i>B</i> street. |
| + 10     |            |        |                | 225.36     |        | 0.0            |             |        |                | In <i>B</i> street.         |
| + 25     |            |        |                | 225.26     |        | X              |             |        |                | Center <i>B</i> street.     |
| 4        |            |        |                | 222.96     |        |                |             |        |                | North Curb <i>B</i> street. |
| 5        |            |        |                | 219.76     |        | - 3.20         |             |        |                |                             |
| 6        |            |        |                | 216.56     |        |                |             |        |                |                             |
| + 05     |            |        |                | 216.40     |        | X              |             |        |                | South Curb <i>C</i> street. |
| + 20     |            |        |                | 216.40     |        | 0.0            |             |        |                | Center <i>C</i> street.     |
| + 35     |            |        |                | 216.40     |        | X              |             |        |                | North Curb <i>C</i> street. |
| 7        |            |        |                | 217.57     |        |                |             |        |                |                             |
| 8        |            |        |                | 219.37     |        | + 1.80         |             |        |                |                             |
| 9        |            |        |                | 221.17     |        |                |             |        |                |                             |
| + 15     |            |        |                | 221.44     |        | X              |             |        |                | South Curb <i>D</i> street. |
| + 30     |            |        |                | 221.44     |        | 0.0            |             |        |                | Center <i>D</i> street.     |

(*b*) The elevation of the grade at the center of *D* street, as computed from the grades and distances and given in the record, is 221.44. Ans.

(1027) (*a*), (*b*), and (*c*) See Art. 1756.

(*d*), (*e*), and (*f*) See Art. 1757.

(1028) (*a*) and (*b*) See Art. 1758.

(*c*) and (*d*) See Art. 1759.

(1029) (*a*) See Art. 1764.

(*b*) See Art. 1765.

(*c*) See Art. 1766.

(*d*) See Art. 1770.

(*c*) and (*f*) See Art. 1771.

(1030) (*a*) and (*b*) See Art. 1772.

(*c*) and (*d*) See Art. 1773.

(*f*) See Art. 1775.

(1031) (*a*) See Art. 1776.

(*b*) and (*c*) See Art. 1777.

(*d*) and (*e*) See Art. 1778.



# PAVING.

(QUESTIONS 1032-1121.)

(1032) See Art. 1779.

(1033) See Art. 1781.

(1034) (See Art. 1782.) By formula 215, the tractive force  $t_o$  will be a force just exceeding the value

$$\frac{1,200 \times \sqrt{(5.2 - .2) \times .2}}{2.6 - .2} = 500 \text{ lb.} \quad \text{Ans.}$$

(1035) By the same formula, the tractive force must just exceed the value

$$\frac{1,200 \times \sqrt{(3.4 - .2) \times .2}}{1.7 - .2} = 640 \text{ lb.} \quad \text{Ans.}$$

(1036) See Art. 1783.

(1037) (a) (See Art. 1784.) From the table of Resistance to Traction, the value of  $c$  for a wooden-block pavement in good condition is found to be  $\frac{1}{75}$ . Hence, for a load of 2 gross tons (=4,480 lb.), the tractive resistance on a level roadway paved with wooden block, as given by formula 216, will be  $\frac{1}{75} \times 4,480 = 60 \text{ lb.}$  Ans.

(b) (See Art. 1785.) By formula 228, Art. 1786, the grade resistance for the same load on an ascending grade of 2.5 per cent. will be

$$\frac{4,480 \times 2.5}{100} = 112 \text{ lb.} \quad \text{Ans.}$$

(c) The total tractive resistance on this grade will, by formula 229, be  $60 + 112 = 172 \text{ lb.}$  Ans.

(1038) (a) From the table of Resistance to Traction, the value of  $c$  for ordinary granite-block pavement is  $\frac{1}{25}$ . Hence, the tractive force required to haul a load of 10,000

pounds on a level roadway paved with such material, as given by formula **216**, is  $\frac{1}{25} \times 10,000 = 400$  lb. Ans.

(b) By formula **228**, the tractive force necessary to overcome the grade resistance will be

$$\frac{10,000 \times 4}{100} = 400 \text{ lb. Ans.}$$

(c) The total tractive force required to haul the load up the grade will, therefore, be given by formula **229**; it is equal to  $400 + 400 = 800$  lb. Ans.

(1039) (a) (See Art. **1787**.) For a wooden block pavement in good condition, the value of  $c$ , as given by the table, is  $\frac{1}{75}$ . Hence, by formula **231**, the per cent. of grade giving the angle of repose for such a pavement will be  $100 \times \frac{1}{75} = 1.33$  per cent. Ans.

(b) For an ordinary granite-block pavement,  $c = \frac{1}{25}$ . (See table.) Hence, the per cent. of grade giving the angle of repose for such a pavement will be  $100 \times \frac{1}{25} = 4.00$  per cent. Ans.

(1040) The value of  $c$  for an asphalt pavement is  $\frac{1}{100}$ . Hence, by formula **231**, the per cent. of grade giving the angle of repose for this pavement is  $100 \times \frac{1}{100} = 1.00$  per cent. By formula **228**, the grade resistance for a load of 3,960 pounds on such a grade will be  $\frac{3,960 \times 1}{100} = 39.6$ , or, near enough, 40 pounds. By formula **215**, the resistance of an obstacle .1 of a foot in height to this load, will be

$$\frac{3,960 \times \sqrt{(5 - .1) \times .1}}{2.5 - .1} = 1,155 \text{ lb.}$$

Hence, the tractive force required to haul the load over the obstacle on this grade must just exceed  $40 + 1,155 = 1,195$  lb. Ans.

(1041) The grade resistance will be the same as in the preceding solution. By formula **215**, the resistance of the obstacle will be

$$\frac{3,960 \times \sqrt{(5.05 - .05) \times .05}}{2.525 - .05} = 800 \text{ lb.}$$

Hence, the required tractive force must just exceed  $40 + 800 = 840$  lb. Ans.

(1042) See Art. 1790.

(1043) See Art. 1791.

(1044) (a) There are 5,280 feet in a mile. A speed of 2 miles per hour is equal to  $2 \times \frac{5,280}{60} = 2 \times 88 = 176$  ft. per min. By formula 232, the tractive force exerted by an ordinary horse at a speed of 2 miles per hour will, therefore, be equal to  $\frac{20,000}{176} = 114$  lb. Ans.

(b) A speed of 3 miles per hour is equal to  $3 \times \frac{5,280}{60} = 3 \times 88 = 264$  ft. per min. By formula 232, the tractive force exerted by an ordinary horse at this speed is  $\frac{20,000}{264} = 76$  lb. Ans.

(c) A speed of 4 miles per hour equals  $4 \times 88 = 352$  ft. per min. The tractive force exerted at this speed is  $\frac{20,000}{352} = 57$  lb. Ans.

(d) At 5 miles per hour, the tractive force exerted is  $\frac{20,000}{5 \times 88} = 45$  lb. Ans.

(e) At 8 miles per hour, the tractive force exerted is  $\frac{20,000}{8 \times 88} = 28$  lb. Ans.

(1045) (a) A speed of 1 mile in 3 minutes is equal to  $\frac{5,280}{3} = 1,760$  ft. per min.

The speed of greatest work will be one-eighth of this (Art. 1791), or  $\frac{1,760}{8} = 220$  ft. per min. Ans.

(b) A speed of 220 feet per minute is equal to

$$\frac{220 \times 60}{5,280} = 2.5 \text{ mi. per hr. Ans.}$$

(c) The average tractive force exerted at this speed will be  $\frac{20,000}{220} = 91$  lb. Ans.

(1046) (a) A speed of 1 mile in 4 minutes is equal to  $\frac{5,280}{4} = 1,320$  ft. per min. The speed of greatest work will, therefore, be  $\frac{1,320}{8} = 165$  ft. per min. Ans.

(b) A speed of 165 ft. per min. is equal to  $\frac{165 \times 60}{5,280} = 1.875$  mi. per hr. Ans.

(c) The average tractive force exerted at this speed will be  $\frac{20,000}{165} = 121$  lb. Ans.

(1047) (a) A speed of 1 mile in 5 minutes is equal to  $\frac{5,280}{5} = 1,056$  ft. per min. The speed of greatest work (Art. 1791) will, therefore, be  $\frac{1,056}{8} = 132$  ft. per min. Ans.

(b) A speed of 132 feet per minute is equal to  $\frac{132 \times 60}{5,280} = 1.5$  mi. per hour. Ans.

(c) The average tractive force exerted at this speed will be  $\frac{20,000}{132} = 152$  lb. Ans.

(d) The tractive force exerted at a dead pull will be double the average tractive force (Art. 1791), or  $\frac{2 \times 20,000}{132} = 303$  lb. Ans.

(1048) (a) The total tractive force required is 172 pounds (Question 1037). As the grade is long, the average tractive force of the horses at the speed of greatest work must be used, instead of their tractive force at a dead pull. The average tractive force exerted by a horse of light weight at the speed of greatest work has been found to be 91 pounds (Question 1045). Hence, two such horses will

exert a tractive force of  $2 \times 91 = 182$  lb., which is sufficient to haul the load of Question 1037 up the grade given in that question, if it were a long grade. Ans.

(b) The tractive force required to be exerted by each horse would be  $1\frac{1}{2}^2 = 86$  lb. Hence, the speed at which these horses could haul the load up the grade would be  $\frac{20,000}{86} = 233$  ft. per min. (nearly). Ans.

(c) This would be equal to  $\frac{233 \times 60}{5,280} = 2.65$  mi. per hr. Ans.

(1049) (a) The total tractive force required is 800 pounds (Question 1038). As it is a long grade, the tractive force at speed of greatest work must be used. For a horse of heavy weight, this tractive force is 152 pounds (Question 1047). Hence, the number of horses required will be  $\frac{800}{152} = 6$  horses. Ans.

(b) The tractive force required to be exerted by each horse is  $\frac{800}{6} = 133\frac{1}{3}$  lb. Hence, the horses could haul the load up the grade at a speed of  $\frac{20,000}{133\frac{1}{3}} = 150$  ft. per min. Ans.

(c) A speed of 150 feet per minute would be equal to  $\frac{150 \times 60}{5,280} = 1.7$  mi. per hr. Ans.

(1050) The total tractive force required must just exceed 1,195 pounds (Question 1040). At a dead pull, one horse of heavy weight can exert a tractive force of 303 pounds (Question 1047). Hence, the number of such horses required will be  $\frac{1,195}{303} = 4$  horses. Ans.

(1051) The total tractive force required is 840 pounds (Question 1041). At the speed of greatest work, a horse of medium weight can exert a tractive force of 121 pounds (Question 1046); at a dead pull, therefore, such a horse can exert a tractive force of  $2 \times 121 = 242$  lb. Hence, the number of horses required will be  $\frac{840}{242} = 4$  horses. Ans.

(1052) From the table of Resistance to Traction, the value of  $c$  for a good granite block pavement is  $\frac{1}{40}$ . Hence, by formula **231**, the per cent. of grade giving the angle of repose for this pavement is  $100 \times \frac{1}{40} = 2.5$  per cent. For a load of 4,000 pounds, the grade resistance on an ascending grade of 2.5 per cent., as given by formula **228**, will be  $\frac{4,000 \times 2.5}{100} = 100$  lb. The rolling resistance for this load on a good granite block pavement, as given by formula **216**, is  $4,000 \times \frac{1}{40} = 100$  lb. Hence, by formula **229**, the total resistance to be overcome by the traction is  $100 + 100 = 200$  lb. At a speed of 200 feet per minute, the average tractive force that can be exerted by one horse, as given by formula **232**, is  $\frac{20,000}{200} = 100$  lb. Hence, the number of horses required would be  $\frac{200}{100} = 2$  horses. Ans.

(1053) The total tractive force required would be  $\frac{5,000 \times 2.5}{100} + 5,000 \times \frac{1}{40} = 250$  lb., or 125 pounds for each horse. By applying formula **232**, it is found that the same horses could haul this load at a speed of  $\frac{20,000}{125} = 160$  ft. per min. Ans.

(1054) (a) For a roadway surface of earth, dry and hard, the value of  $c$ , as given by the table of Resistance to Traction, is  $\frac{1}{22}$ . Hence, for this material, the per cent. of grade giving the angle of repose, as given by formula **231**, is  $100 \times \frac{1}{22} = 4.55$  per cent. Ans.

(b) For a hard rolled gravel roadway,  $c = \frac{1}{30}$  (see table), and by formula **231**, the per cent. of grade giving the angle of repose for this material is  $100 \times \frac{1}{30} = 3.33$  per cent. Ans.

(c) For a good cobblestone pavement, the value of  $c$  is the same as for the preceding. Hence, the per cent. of grade giving the angle of repose for this material is also 3.33 per cent. Ans.

(d) For the best macadam pavement, the value of  $c$  is  $\frac{1}{45}$ . Hence, the per cent. of grade giving the angle of

repose for this material, as given by formula **231**, is  $100 \times \frac{1}{45} = 2.22$  per cent. Ans.

(*e*) For the best granite-block pavement, the value of  $c$  is  $\frac{1}{66}$ , and the per cent. of grade necessary to give the angle of repose is  $100 \times \frac{1}{66} = 1.52$  per cent. Ans.

(**1055**) (*a*) From the table referred to, the value of  $c$  for a roadway surface of ordinary earth is  $\frac{1}{11}$ , and, by formula **231**, the per cent. of grade giving the angle of repose is  $100 \times \frac{1}{11} = 9.09$  per cent. Ans.

(*b*) For a common gravel roadway, the value of  $c$  is  $\frac{1}{16}$ , and the per cent. of grade giving the angle of repose is  $100 \times \frac{1}{16} = 6.25$  per cent. Ans.

(*c*) For an ordinary cobblestone pavement, the value of  $c$  is the same as for the preceding, and the per cent. of grade giving the angle of repose is also 6.25 per cent. Ans.

(*d*) For an ordinary macadam pavement, the value of  $c$  is  $\frac{1}{25}$ , and the per cent. of grade giving the angle of repose is  $100 \times \frac{1}{25} = 4.00$  per cent. Ans.

(*e*) For an ordinary granite pavement, the value of  $c$  is the same as for the preceding, and the per cent. of grade giving the angle of repose is also 4.00 per cent. Ans.

(**1056**) The value of  $c$  for a good granite-block pavement is  $\frac{1}{40}$ . Hence, by formula **231**, the per cent. of grade giving the angle of repose for such a pavement will be  $100 \times \frac{1}{40} = 2.50$  per cent. By formula **229**, the total tractive resistance of such a pavement would be  $w \left( \frac{2.50}{100} + \frac{1}{40} \right)$ .

By placing this equal to the total tractive resistance of an asphalt pavement, for which  $c = \frac{1}{66}$ , we have the equation

$w \left( \frac{2.50}{100} + \frac{1}{40} \right) = w \left( \frac{r_{100}}{100} + \frac{1}{100} \right)$ , from which  $r_{100} = 4$  per cent.

Ans.

(**1057**) The value of  $c$  for a good cobblestone pavement is  $\frac{1}{30}$ . As there is no grade resistance, the total tractive resistance is given by formula **216**, and is  $\frac{w}{30}$ . For the

best macadam pavement the value of  $c$  is  $\frac{1}{45}$ . By applying formula **229**, we have the equation  $\frac{w}{30} = w \left( \frac{r_{100}}{100} + \frac{1}{45} \right)$ , from which  $r_{100} = 1.11$  per cent. Ans.

(**1058**) A speed of 2.5 miles per hour is equal to  $\frac{2.5 \times 5,280}{60} = 220$  ft. per min. Formula **232** gives for the

average value of the tractive force of one horse  $t' = \frac{20,000}{s'}$ ,

where  $s'$  is the speed. In order that the tractive force exerted by two horses may be just equal to that exerted by one horse at a certain speed, the speed of the two horses must be such that the tractive force exerted by each will be equal to  $\frac{t'}{2}$ . By formula **232**,  $\frac{t'}{2} = \frac{20,000}{2s'}$ , showing that the speed of the two horses for this condition must be equal to twice the speed of one horse, or  $2 \times 220 = 440$  ft. per min. Ans.

(**1059**) See Art. **1794**.

(**1060**) See Arts. **1796** and **1797**.

(**1061**) See Art. **1798**.

(**1062**) See Art. **1800**.

(**1063**) See Arts. **1801** and **1802**.

(**1064**) See Art. **1803**.

(**1065**) See Art. **1804**.

(**1066**) See Art. **1805**.

(**1067**) The mean life of a granite-block pavement is 21 years (Table 37, Art. **1802**). The first cost, on a sand or gravel foundation, is 2.80 dollars per square yard (Table 38, Art. **1806**), and the cost of the concrete foundation is 90 cents per square yard (Art. **1806**), making a total cost of  $2.80 + .90 = 3.70$  dollars per square yard. The final value of the foundation and old surface material will be



$.90 + .80 = 1.70$  dollars per square yard (Art. **1807**). A piece of pavement 1 yard in length on a roadway 10 yards wide will contain  $10 \times 1 = 10$  sq. yd. Hence, the annual charge against this piece of pavement for first cost, as given by formula **234**, will be equal to  $10 \times \frac{3.70 - 1.70}{21} + 10 \times .04 \times 3.70 = 2.432$  dollars. Ans.

(**1068**) See Arts. **1809**, **1810**, and **1811**.

(**1069**) (*a*) The annual cost of the maintenance of 10 square yards of granite-block pavement (Table 40, Art. **1809**) is  $10 \times 2 = 20$  cents. Ans.

(*b*) The annual cost of cleaning and sprinkling 10 square yards of stone-block pavement (Table 41, Art. **1810**) is  $10 \times 10 = 100$  cents. Ans.

(*c*) The annual service cost for 10 square yards of stone-block pavement (Table 42, Art. **1811**) is  $10 \times 40 = 400$  cents. Ans.

(*d*) The annual charge for consequent damages against 10 square yards of stone-block pavement (Table 43, Art. **1812**) is  $10 \times 10 = 100$  cents. Ans.

(**1070**) By substituting the results obtained for Questions 1067 and 1069 in formula **233**, the total annual expense chargeable against the 10 square yards of pavement described in Question 1067 is found to be equal to  $2.432 + .20 + 1.00 + 4.00 + 1.00 = 8.632$  dollars. Ans.

(**1071**) (*a*) By substituting the number of vehicles of each class and the number of days of observation in formula **235**, the average daily tonnage  $d_t$  on the roadway is found to be  $\frac{\frac{1}{2} \times 2,464 + 2 \times 2,080 + 4 \times 810}{4} = 2,158$  tons. Ans.

(*b*) As the roadway is 10 yards = 30 ft. wide, the average daily tonnage per foot of width is equal to  $\frac{2,158}{30} = 72$  tons. Ans.

(**1072**) By substituting in formula **236** the length of the pavement and the results obtained for Questions 1070

and 1071 (*a*), expressing the annual cost in cents, the average cost to the traffic per ton-yard is found to be equal to

$$\frac{863.2}{365 \times 2,158 \times 1} = .0011 \text{ of a cent. Ans.}$$

(1073) (*a*) The mean life of the brick pavement would be 10 years (Table 37, Art. 1802). The first cost would be  $1.90 + .90 = 2.80$  dollars per square yard (Table 38, Art. 1806). The final value of the foundation and old surface material will be  $.90 + .20 = 1.10$  dollars per square yard. Hence, by formula 234, the annual charge against the 10 yards of pavement for first cost will be  $10 \times \frac{2.80 - 1.10}{10} + 10 \times .04 \times 2.80 = 2.82$  dollars. The other annual expenses will be as follows: for maintenance (Table 40, Art. 1809),  $10 \times 5 = 50$  cents; for cleaning and sprinkling (Table 41, Art. 1810),  $10 \times 5 = 50$  cents; for annual service cost (Table 42, Art. 1811),  $10 \times 20 = 200$  cents; and for consequent damages (Table 43, Art. 1812),  $10 \times 5 = 50$  cents. The total annual expense chargeable against these 10 yards of pavement is, therefore, equal to  $2.82 + .50 + .50 + 2.00 + .50 = 6.32$  dollars. Ans.

(*b*) By substituting in formula 236 this total annual cost, expressed in cents, the average daily tonnage as obtained for Question 1071 (*a*), and the length of the piece of pavement, the average cost to the traffic per ton-yard is found to be equal to  $\frac{632}{365 \times 2,158 \times 1} = .0008$  of a cent. Ans.

(1074) The total annual cost will be 632 cents, the same as in the preceding question. The average daily tonnage over the full width (30 feet) of roadway will be  $30 \times 55 = 1,650$  tons. By substituting these values in formula 236, and remembering that the piece of pavement is 1 yard in length, the average cost per ton-yard to the traffic is found to be equal to  $\frac{632}{365 \times 1,650 \times 1} = .00105$  of a cent., Ans.

(1075) (*a*) The roadway is 36 feet = 12 yards wide and, in a length of 1 yard, contains 12 square yards of

pavement. The mean life of an asphalt pavement is 12 years (Table 37, Art. **1802**). The first cost of this pavement on concrete foundation is 3.00 dollars per square yard (Table 38, Art. **1806**), and the final value of the foundation and old surface material will be  $.90 + .10 = 1.00$  dollar per square yard (Table 39, Art. **1807**). Hence, by formula **234**, the annual charge against the pavement for first cost will be equal to  $12 \times \frac{3.00 - 1.00}{12} + 12 \times .04 \times 3.00 =$

3.44 dollars. The other annual expenses will be as follows: for maintenance (Table 40, Art. **1809**),  $12 \times 9 = 108$  cents; for cleaning and sprinkling (Table 41, Art. **1810**),  $12 \times 2 = 24$  cents; for annual service cost (Table 42, Art. **1811**),  $12 \times 15 = 180$  cents; and for consequent damages (Table 43, Art. **1812**),  $12 \times 2 = 24$  cents, making the total annual expense chargeable against the piece of pavement equal to  $3.44 + 1.08 + .24 + 1.80 + .24 = 6.80$  dollars. Ans.

(b) By substituting the number of vehicles of each class, and the number of days' observation, in formula **235**, the average daily tonnage is found to be

$$\frac{\frac{1}{2} \times 2,460 + 2 \times 1,115 + 4 \times 260}{5} = 900 \text{ tons.}$$

By substituting in formula **236**, the total annual cost, expressed in cents, the average daily tonnage, and the length of the piece of pavement, the average cost per ton-yard to the traffic is found to be  $\frac{680}{365 \times 900 \times 1} = .00207$  of a cent. .  
Ans.

(1076) See Arts. **1823** and **1824**.

(1077) See Arts. **1825** and **1826**.

(1078) See Art. **1828**.

(1079) See Art. **1829**.

(1080) See Art. **1829**.

(1081) See Arts. **1830** and **1831**.

- (1082) See Art. **1832**.
- (1083) See Arts. **1833** to **1836**.
- (1084) See Art. **1838**.
- (1085) See Art. **1839**.
- (1086) See Art. **1841**.
- (1087) See Art. **1842**.
- (1088) See Art. **1843**.
- (1089) See Arts. **1844** and **1845**.
- (1090) See Arts. **1846** and **1847**.
- (1091) See Arts. **1848** to **1851**.
- (1092) See Art. **1852**.
- (1093) See Arts. **1854** and **1855**.
- (1094) See Arts. **1856** and **1857**.
- (1095) See Arts. **1858** to **1861**.
- (1096) See Art. **1862**.
- (1097) See Art. **1863**.
- (1098) See Arts. **1864**, **1865**, and **1866**.
- (1099) See Arts. **1867** and **1868**.
- (1100) See Art. **1869**.
- (1101) See Art. **1870**.
- (1102) See Arts. **1871** and **1872**.
- (1103) See Arts. **1873** and **1874**.
- (1104) See Arts. **1875** and **1876**.
- (1105) See Arts. **1877** and **1878**.
- (1106) See Arts. **1879** and **1880**.
- (1107) See Arts. **1881** to **1883**.
- (1108) See Arts. **1884** to **1886**.
- (1109) See Arts. **1887** to **1889**.

- (1110) See Arts. **1891** to **1894**.
- (1111) See Arts. **1895** to **1897**.
- (1112) See Arts. **1898** to **1901**.
- (1113) See Art. **1903**.
- (1114) See Arts. **1904** and **1905**.
- (1115) See Art. **1906**.
- (1116) See Art. **1907**.
- (1117) See Art. **1908**.
- (1118) See Art. **1909**.
- (1119) See Art. **1903**.
- (1120) See Art. **1911**.
- (1121) See Art. **1913**.



# WATER-WHEELS.

(QUESTIONS 946-998.)

(946) Applying formula **122**, Art. **1730**,

$$\text{H. P.} = \frac{21 \times 62.5 \times 14}{550} = 33.4. \quad \text{Ans.}$$

(947) The quantity of water that will be available for the 10 working hours is  $21 \times \frac{24}{10} = 50.4$  cubic feet per second; therefore, the theoretical horsepower will be

$$\frac{50.4 \times 62.5 \times 14}{550} = 80\frac{2}{11} \text{ H. P.}$$

Applying rule **I**, Art. **1737**, the available work is

$$80\frac{2}{11} \times .75 = 60.136 \text{ H. P.} \quad \text{Ans.}$$

(948) Applying formula **123**, Art. **1731**,

$K = c^2 W h = .98^2 \times 18 \times 62.5 \times 75 = 81,033.75$  foot-pounds per second. Ans.

(949) Applying formula **126**, Art. **1732**,

$$P = W \frac{v}{g} = 7 \times 62.5 \times \frac{23}{32.16} = 312.888 \text{ pounds.} \quad \text{Ans.}$$

(950) The weight of water flowing in the jet is

$$W = .25 \times 38 \times 62.5 = 593.75 \text{ pounds per second.}$$

Applying formula **129**, Art. **1735**, and remembering that, since the jet is perpendicular to the surface,  $\alpha = 90^\circ$  and  $\cos \alpha = 0$ ,

$$P = (1 - \cos \alpha) W \left(1 - \frac{v'}{v}\right) \frac{v - v'}{g} =$$

$$593.75 \times \left(1 - \frac{10}{38}\right) \times \frac{38 - 10}{32.16} =$$

$$593.75 \times \frac{14}{19} \times \frac{28}{32.16} = 380.91 \text{ pounds.} \quad \text{Ans.}$$

(951) Applying formula **128**, Art. **1734**, and substituting,

$$P = (1 - \cos \alpha) W \frac{v}{g} = (1 - .866) \times 593.75 \times \frac{38}{32.16} = 94.01 \text{ pounds. Ans.}$$

(952) In accordance with the principles of Hydro-mechanics, the head that would produce a pressure of 125 pounds per square inch is  $h = \frac{125}{.434}$  feet; and the velocity of flow from the nozzle is

$$v = .98 \sqrt{2 g h} = .98 \times 8.02 \sqrt{\frac{125}{.434}} = 133.385 \text{ feet per second.}$$

In accordance with the principles developed in Art. **1735**, the water will leave a hemispherical cup with no absolute velocity when the velocity of the cup is equal to one-half the velocity of the jet; hence, the velocity of the cup must be  $133.385 \div 2 = 66.692$  feet per second. Ans.

(953) Since the water leaves the cup with no absolute velocity, all its energy has been imparted to the cup. Hence, the energy imparted to the cup equals the energy that existed in the jet. From formula **121**, Art. **1727**, energy is

$$K = W \frac{v^2}{2g} = 2\frac{1}{2} \times 62.5 \times \frac{133.385^2}{64.32} = 43,220.31 \text{ foot-pounds per second. Ans.}$$

(954) The theoretical horsepower in the water is, from formula **122**, Art. **1730**,

$$\frac{36 \times 62.5 \times 23}{550} = 94.091 \text{ H. P.}$$

Hence, according to the definition of efficiency given in Art. **1737**, the efficiency is

$$62\frac{1}{2} \div 94.091 = .66425 = 66.425 \text{ per cent. Ans.}$$

(955) The theoretical horsepower is

$$\frac{2.75 \times 62.5 \times 482}{550} = 150.625 \text{ H. P.}$$



The theoretical power in the water due to the pressure at the nozzle is the same as the theoretical power that would be developed if the water were to fall freely through a height equal to the head required to produce the given pressure. Since a head of 1 foot produces a pressure of .434 pound per square inch, the head that would produce a pressure of 192 pounds per square inch is  $\frac{192}{.434}$ , and the theoretical horsepower due to the pressure is

$$\frac{2.75 \times 62.5 \times \frac{192}{.434}}{550} = 138.241 \text{ H. P.}$$

(a) Since the wheel develops 92 horsepower, it uses the water delivered to the nozzle with an efficiency of

$$\frac{92}{138.241} = .6655 = 66.55 \text{ per cent. Ans.}$$

(b) The efficiency of the whole plant is equal to the horsepower actually developed, divided by the total theoretical horsepower =

$$\frac{92}{150.625} = .61079 = 61.079 \text{ per cent. Ans.}$$

(956) The total theoretical power in the water used is

$$\frac{78 \times 62.5 \times 7.5}{550} = 66.476 \text{ H. P.}$$

(a) The power lost through the resistances in the pipe is equal to the amount of power that would be developed if the water were to fall freely through a distance equal to the loss in head, or

$$\frac{78 \times 62.5 \times .32}{550} = 2.836 \text{ H. P. Ans.}$$

(b) The loss in efficiency due to resistances in the pipe is equal to the loss in power due to those resistances divided by the total theoretical power =

$$\frac{2.836}{66.476} = .04267 = 4.267 \text{ per cent. Ans.}$$

(957) The theoretical weight  $W$  of water required per second to furnish 75 horsepower with a fall of 40 feet is equal to the total number of foot-pounds of work that must be done in one second, divided by 40, the distance in feet through which the water falls; therefore,

$$W = \frac{75 \times 550}{40} = 1,031.25 \text{ pounds per second;}$$

and, from rule II, Art. 1737, the total weight required is

$$\frac{1,031.25}{.68} = 1,516.5 \text{ pounds.}$$

$$\frac{1,516.5}{62.5} = 24.264 \text{ cu. ft. Ans.}$$

(958) (a) The velocity of entrance, from the conditions of the problem, is

$$v_e = 1\frac{1}{2} \times .6 = 9 \text{ feet per second;}$$

therefore, applying formula 132, Art. 1743,

$$h = 1.1 \frac{v_e^2}{2g} = 1.1 \times \frac{9^2}{64.32} = 1.385 \text{ feet. Ans.}$$

(b) The diameter  $D$  of the wheel (see Art. 1743) is equal to the total head  $H$  minus the head  $h$  and the clearance between the wheel and trough; i. e.,

$$D = 23 - (1.385 + .125) = 21.49 \text{ feet,}$$

or, in even numbers,  $21\frac{1}{2}$  feet. Ans.

(c) Applying formula 133, and substituting,

$$N = 19.1 \frac{v}{D} = 19.1 \times \frac{6}{21.5} = 5.33. \text{ Ans.}$$

(d) From formula 134,  $Z = 2\frac{1}{2} D$  to  $3 D$ ; choosing the former value,

$$Z = 2\frac{1}{2} D = 2\frac{1}{2} \times 21.5 = 53.75, \text{ say } 54. \text{ Ans.}$$

(e) Assuming a mean value for the coefficient in formula 136, and substituting,

$$b = 3.5 \frac{Q}{dv} = 3.5 \times \frac{2.5}{1 \times 6} = 1.45\frac{5}{8} \text{ feet} = 17\frac{1}{2}, \text{ say } 18 \text{ inches.}$$

Ans.

(959) (a) See Arts. **1741** and **1744** to **1747**.

(b) See Arts. **1751** and **1752**.

(960) Since the velocity of the circumference of the wheel should be one-half the velocity of the current (see Art. **1753**), the velocity of the circumference is

$$v = \frac{9}{2} = 4\frac{1}{2} \text{ feet per second;}$$

and, from formula **133**, Art. **1743**,

$N = 19.1 \frac{v}{D} = 19.1 \times \frac{4.5}{14} = 6.1$  revolutions per minute,  
say 6 per minute. Ans.

(961) The quantity of water  $Q$  flowing in the stream is

$$Q = av = 6 \times 1\frac{1}{2} \times 10\frac{1}{2} = 94\frac{1}{2} \text{ cubic feet per second;}$$

hence, assuming the velocity of the circumference of the wheel to be equal to one-half of the velocity of the current, and applying formula **137**, Art. **1754**,

$$\text{H. P.} = .00215 (v - v_1) v_1 Q = .00215 \times (10\frac{1}{2} - 5\frac{1}{4}) \times 5\frac{1}{4} \times 94\frac{1}{2} = 5.6.$$

Ans.

(962) (a) and (b) See Art. **1763**.

(963) The velocity with which the water flows from the nozzle is

$$v = .98 \times \sqrt{2gh} = .98 \times 8.02 \sqrt{\frac{80}{.434}} = 106.71 \text{ feet per second;}$$

and, since the maximum efficiency is obtained when the circumferential velocity of the wheel equals one-half the velocity of the jet (see Art. **1764**), the velocity of the circumference is  $106.71 \div 2 = 53.36$  feet per second. Hence, applying formula **133**, Art. **1743**,

$$N = 19.1 \frac{v}{D} = 19.1 \times \frac{53.36}{2} = 509.5 \text{ rev. per min. Ans.}$$

(964) The velocity with which the water flows from the nozzle is

$$v = .98 \sqrt{2gh} = .98 \times 8.02 \sqrt{285} = 132.685 \text{ feet per second;}$$

hence, as in the last example, the velocity of the cups should be

$$132.685 \div 2 = 66.342 \text{ feet per second.}$$

Applying formula **133**, Art. **1743**,

$$N = 19.1 \frac{v}{D}, \text{ or } D = 19.1 \frac{v}{N}, \text{ we have}$$

$$D = 19.1 \times \frac{66.342}{250} = 5.06 \text{ feet, say 5 feet. Ans.}$$

(965) (a) and (b) See Arts. **1770** and **1771**.

(966) Because, when the water leaves the wheel with a considerable absolute velocity, it carries a considerable quantity of energy with it which has not been utilized in doing work. (Art. **1731**.)

(967) See Art. **1762**.

(968) See Art. **1769**.

(969) See Art. **1772**.

(970) See Art. **1773**.

(971) (a) See Arts. **1792** and **1793**.

(b) See Arts. **1790** and **1791**.

(972) Applying formula **149**, Art. **1796**,

$$e_2 = \frac{Q}{Z_1 x_2 v_2} = \frac{33}{27 \times \frac{1.9}{12} \times 19\frac{1}{2}} = .48134 \text{ feet} = 5\frac{3}{4} \text{ inches. Ans.}$$

(973) (a) and (b) See Art. **1799**.

(974) (a) See Art. **1741**.

(b) See Art. **1748**.

(c) See Art. **1756**.

(975) Applying formula **149**, Art. **1796**,

$$e_2 = \frac{Q}{Z_1 x_2 v_2} = \frac{85}{28 \times \frac{3.25}{12} \times 21} = .5337 \text{ feet} = 6\frac{1}{16} \text{ inches. Ans.}$$

(976) Applying formula **133**, Art. **1743**,

$$D = 19.1 \times \frac{v}{N} = 19.1 \times \frac{19.5}{125} = 2.979 \text{ feet,}$$

from which  $r = \frac{1}{2} D = 1.489$ , or, in even numbers,  $r = 1\frac{1}{2}$  feet = 18 inches. Ans.

(977) See Art. 1803.

(978) The head required to produce the velocity with which the water leaves the draft tube is

$$h = \frac{v^2}{2g} = \frac{10^2}{64.32} = 1.5547 \text{ feet};$$

therefore, since the energy in the water is directly proportional to the head (see Art. 1727), the proportion of the total energy lost in producing the velocity of discharge is

$$1.5547 \div 18 = .08637 = 8.637 \text{ per cent. Ans.}$$

(979) See Art. 1804.

(980) The loss in head is 12 feet  $- 8\frac{1}{2}$  feet  $= 3\frac{1}{2}$  feet; hence, since the available energy is directly proportional to the head (see Art. 1727), the loss is

$$3\frac{1}{2} \div 12 = .29167 = 29.167 \text{ per cent.}$$

of the original energy, and there is a consequent loss in efficiency of 29.167 per cent. Ans.

(981) (a) and (b) See Art. 1809.

(982) See Art. 1809.

(983) See Art. 1768.

(984) (a) See Arts. 1812, 1815, and 1818.

(b) See Art. 1812.

(985) See Art. 1813.

(986) See Art. 1814.

(987)  $A = \frac{Q}{v} = \frac{75}{2} = 37.5 \text{ sq. ft. Ans.}$

(988) See Art. 1794.

(989) See Art. 1832.

(990) The theoretical weight  $W$  of water required per second to furnish 125 horsepower with a head of 32 feet is

equal to the total number of foot-pounds of work that must be done in one second, divided by 32, the distance in feet through which the water falls; therefore,

$$W = \frac{125 \times 550}{32} = 2,148.437 \text{ pounds per second;}$$

and, from rule II, Art. 1737, the total weight required is

$$\frac{2,148.437}{10} = 214.8437 \text{ pounds per second.}$$

$$\frac{214.8437}{62.5} = 3.437 \text{ cu. ft. per second. Ans.}$$

(991) Since the average flow per second during the summer is  $3\frac{1}{2}$  cubic feet, the water that will be furnished by the flow of the stream, if used during 10 hours out of the 24, will be  $3\frac{1}{2} \times \frac{10}{24} = 1.458$  cubic feet per second.

The supply from the reservoir will furnish

$$\frac{22,000,000}{92 \times 10 \times 60 \times 60} = 3.942 \text{ cubic feet per second}$$

for an average of 10 hours per day during the 92 days of the summer; hence, the total available flow is  $1.458 + 3.942 = 5.4$  cu. ft. per second, and the horsepower with an efficiency of .68 per cent, is

$$\frac{5.4 \times 62.5 \times 25}{550} \times .68 = 29 \text{ H. P., nearly. Ans.}$$

(992) (a) See Art. 1741.

(b) See Art. 1756.

(c) See Art. 1759.

(d) See Art. 1812.

(e) See Art. 1770.

(993) (a) See Arts. 1759 to 1763.

(b) See Arts. 1767 to 1771.

(994) Applying formula 138, Art. 1753,

$$\text{H. P.} = \frac{.00283 \times (12 - 6) \times 12 \times 6 \times (5 \times 14)}{1} = 9.137. \text{ Ans.}$$

(995) The velocity of flow from the nozzle is

$v = .99 \sqrt{2gh} = .99 \times 8.02 \times \sqrt{150} = 217.44$  feet per second;  
therefore, the area of the nozzle must be

$$A = \frac{Q}{v} = \frac{3.5}{217.44} = .016096 \text{ sq. feet, or } .016096 \times 144 = 2.3178 \text{ square inches.}$$

The diameter corresponding to this area is

$$d = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{2.3178}{.7854}} = 1.7179 \text{ inches} = 1\frac{23}{32} \text{ inches. Ans.}$$

(996) The head equivalent to the absolute velocity with which the water leaves the wheel is

$$h' = \frac{v^2}{2g} = \frac{8^2}{64.32} = .995 \text{ feet,}$$

and the head lost in the fall from the wheel to the tail water is 10 inches = .833 feet, making a total loss in head, when the water is discharged from the wheel, of  $.995 + .833 = 1.828$  feet. Since the loss in energy is proportional to the loss in head, the percentage of the original energy lost is

$$\frac{1.828}{45} = .04062 = 4.062 \text{ per cent. Ans.}$$

(997) The area of the draft tube must be

$$A = \frac{Q}{v} = \frac{80}{4} = 20 \text{ square feet;}$$

and the diameter

$$d = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{20}{.7854}} = 5.046 \text{ feet,}$$

or, in even numbers, 5 feet. Ans.

(998) The outflow area from the guide vanes must be

$$A = \frac{Q}{v_e} = \frac{28}{33} = .8485 \text{ square feet.}$$

Applying formula 147, Art. 1795,

$$e = \frac{A}{Zx - Z_1s} = \frac{.8485 \times 144}{28 \times 1.625 - 22 \times \frac{3}{16}} = 2.953 \text{ inches,}$$

or 3 inches, nearly. Ans.





# HYDRAULIC MACHINERY.

(QUESTIONS 999-1058.)

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- (999) See Art. 1837.  
(1000) See Art. 1837.  
(1001) See Arts. 1839 and 1848.  
(1002) (a) See Art. 1841.  
(b) See Art. 1842.  
(c) See Art. 1862.  
(1003) See Art. 1852.  
(1004) (a) See Art. 1849.  
(b) See Art. 1842.  
(c) See Art. 1861.  
(d) See Art. 1863.  
(1005) See Art. 1865.  
(1006) See Art. 1852.  
(1007) See Art. 1858.  
(1008) See Arts. 1870 and 1871.  
(1009) See Art. 1883.  
(1010) See Art. 1888.  
(1011) See Art. 1890.

(1012) Since the pump is to work under ordinary conditions, we may make the volume of the air-chamber about three times the piston displacement for a single stroke. (See Art. 1885.) From the rule given in Art. 1905, the displacement for a single stroke is  $22 \times .7854 \times 8^2 \times 1 = 1,105.843$  cu. in.; therefore, the size of the air-

chamber will be  $1,105.843 \times 3 = 3,317.529$  cu. in. = 2 cu. ft., nearly. Ans.

(1013) See Art. 1890.

(1014) See Art. 1891.

(1015) See Art. 1897.

(1016) See Art. 1898.

(1017) See Arts. 1899 to 1902.

(1018) See Arts. 1903 and 1904.

(1019) Applying rule, Art. 1905, the displacement is found to be

$$1\frac{6}{8} \times 2 \times 75 \times \frac{.7854 \times 8^2}{144} = 69.813 \text{ cu. ft. per min. Ans.}$$

(1020) The displacement in gallons per minute is  $69.813 \times 7.48 = 522.2$ ; therefore, using rule in Art. 1909, the slip is  $\frac{522.2 - 450}{522.2} = .1383 = 13.83$  per cent. Ans.

(1021) See Art. 1909.

(1022) In accordance with the definition given in Art. 1910, the useful work is

$$325 \times 8\frac{1}{8} \times 280 = 758,333\frac{1}{8} \text{ ft.-lb. per min. Ans.}$$

(1023) The number of gallons discharged per minute is  $\frac{8,000}{60}$ , and the plunger speed is  $7 \times 10 = 70$  feet per minute; therefore, applying formula 152, Art. 1916, and substituting, we have

$$d = 5.535 \sqrt{\frac{G}{S}} = 5.535 \sqrt{\frac{8,000}{60 \times 70}} = 7.639 \text{ in.} = 7\frac{5}{8} \text{ in., nearly.}$$

Ans.

(1024) (a) Applying formula 152, Art. 1916, and substituting, the diameter of the plunger is

$$d = 5.535 \sqrt{\frac{G}{S}} = 5.535 \sqrt{\frac{750}{100}} = 15.158 \text{ in.} = 15 \text{ in., say. Ans.}$$

(b) Applying formula **158**, Art. **1921**, and substituting, the size of the suction-pipe is

$$d_1 = .35 \sqrt{G} = .35 \sqrt{750} = 9.585 \text{ in.};$$

therefore, make the suction-pipe 10 in. Ans.

(c) Applying formula **159**, Art. **1921**, and substituting, the diameter of the delivery-pipe is

$$d_2 = .25 \sqrt{G} = .25 \sqrt{750} = 6.847 \text{ in.};$$

therefore, make the delivery-pipe 7 in. Ans.

(**1025**) (a) 200 gallons per minute = discharge for both sides of pump,  $200 \div 2 = 100$  gallons for each pump. Applying formula **152**,

$$d = 5.535 \sqrt{\frac{G}{S}} = 5.535 \sqrt{\frac{100}{150}} = 4\frac{1}{2} \text{ in. Ans.}$$

(b) Applying formula **158**, Art. **1921**, and substituting,

$$d_1 = .35 \sqrt{G} = .35 \sqrt{200} = 4.95 \text{ in.};$$

therefore, make  $d_1 = 5$  in. Ans.

(c) Applying formula **159**, Art. **1921**, and substituting,

$$d_2 = .25 \sqrt{G} = .25 \sqrt{200} = 3.536 = 3\frac{1}{2} \text{ in., say. Ans.}$$

(d) Applying formula **154**, Art. **1918**, and substituting,

$$H = .00038 G h = .00038 \times 200 \times 250 = 19 \text{ H. P. Ans.}$$

(**1026**) (a) The number of gallons that will be discharged per minute by one pump is found by applying formula **153**, Art. **1917**. Substituting in the formula,  $G = .03264 d^2 S = .03264 \times 14^2 \times 100 = 639.744$  gal.; the discharge per minute for the two pumps is  $639.744 \times 2 = 1,279.488$  gal.; and the discharge per hour is  $1,279.488 \times 60 = 76,769.28$  gal. Ans.

(b) The horsepower of the pump is equal to the quotient obtained by dividing the product of the area of the steam cylinders, the steam pressure, and the plunger speed in feet per minute by 33,000, or

$$H = \frac{380.13 \times 2 \times 45 \times 100}{33,000} = 103.67;$$

therefore, substituting in formula **155**, Art. **1919**,

$$h = \frac{H}{.00038 G} = \frac{103.67}{.00038 \times 1,279.488} = 213 \text{ ft. Ans.}$$

(1027) (a) The theoretical horsepower is equal to the number of foot-pounds of useful work done in one minute divided by 33,000, or

$$\frac{80,000 \times 8\frac{1}{2} \times 420}{33,000 \times 60} = 141.41 \text{ H. P. Ans.}$$

(b) Applying formula **154**, Art. **1918**, and substituting,  
 $H = .00038 G h = .00038 \times \frac{80,000}{60} \times 420 = 212.8 \text{ H. P. Ans.}$

(1028) Applying formula **160**, Art. **1922**, and substituting,

$$D = \frac{835.5 G h}{W} = \frac{835.5 \times 30,000 \times 290}{600} = 12,114,750 \text{ ft.-lb. Ans.}$$

(1029) (a) Applying formula **153**, Art. **1917**, and substituting,

$$G = .03264 d^2 S = .03264 \times 15^2 \times 100 = 734.4 \text{ gal. per min. Ans.}$$

(b) First find the required horsepower. By substituting the number of gallons just obtained in formula **154**, Art. **1918**,

$$H = .00038 \times 734.4 \times 310 = 86.51 \text{ H. P.}$$

Now substituting in formula **157**, Art. **1920**, we have for the diameter of the steam cylinder,

$$d = \sqrt{\frac{42,016.8 \times 86.51}{50 \times 100}} = 26.96 \text{ in. ;}$$

therefore, make the diameter of the steam cylinder 27 inches. Ans.

(1030) (a) Applying formula **153**, Art. **1917**, and substituting,

$$G = .03264 d^2 S = .03264 \times 11^2 \times 100 = 394.944 \text{ gal. per min.} = 394.944 \times 60 = 23,696.64 \text{ gal. per hr. Ans.}$$

(b) Applying formula **154**, Art. **1918**, and substituting,  
 $H = .00038 G h = .00038 \times 394.944 \times 300 = 45.024$  H. P.

Ans.

(c) Applying formula **157**, Art. **1920**, and substituting,

$$d = \sqrt[4]{\frac{42,016.8 \times H}{P \times S}} = \sqrt[4]{\frac{42,016.8 \times 45.024}{50 \times 100}} = 19.45, \text{ say } 19\frac{1}{2} \text{ in.} \quad \text{Ans.}$$

(1031) First find the theoretical horsepower,

$$\text{H. P.} = \frac{18,000 \times 8\frac{1}{2} \times 225}{33,000 \times 60} = 17.045.$$

The actual horsepower required is  $17.045 \times 1.5 = 25.568$  H. P.

By applying formula **157**, Art. **1920**, we get for the diameter of the steam cylinder,

$$d = \sqrt[4]{\frac{42,016.8 \times 25.568}{50 \times 110}} = 13.976, \text{ or } 14 \text{ in., say.} \quad \text{Ans.}$$

The diameter of the water plunger is found by substituting in formula **152**, Art. **1916**,

$$d = 5.535 \sqrt[4]{\frac{G}{S}} = 5.535 \sqrt[4]{\frac{18,000}{60 \times 110}} = 9.138, \text{ or } 9\frac{1}{8} \text{ in., say.} \quad \text{Ans.}$$

The length of stroke may be taken as 12 inches, in accordance with good practice.

To find the diameter of the suction-pipe, apply formula **158**, Art. **1921**; whence,

$$d_1 = .35 \sqrt[4]{\frac{18,000}{60}} = 6.062 = 6 \text{ in., say.} \quad \text{Ans.}$$

For the discharge-pipe, from formula **159**, same article,

$$d_2 = .25 \sqrt[4]{\frac{18,000}{60}} = 4.33 \text{ in.;}$$

therefore, make the diameter  $4\frac{1}{2}$  in. Ans.

(1032) The total work done is

$$W = 218 \times 3,240,000 \times 8\frac{1}{2} = 5,886,000,000 \text{ ft.-lb.;}$$

therefore, applying formula **162**, Art. **1924**, and substituting,

$$D = \frac{W}{H} \times 1,000,000 = \frac{5,886,000,000}{67,655,170} \times 1,000,000 = 87,000,000 \text{ ft.-lb.} \quad \text{Ans.}$$

(1033) The area of the plunger is

$$\frac{.7854 \times 14^2}{144} = 1.07 \text{ square feet, nearly.}$$

Since there are two pumps, the displacement, according to rule, Art. **1905**, is  $1.07 \times 100 \times 2 = 214$  cubic feet per minute. The discharge is

$$\frac{75,000}{60 \times 7.48} = 167.112 \text{ cubic feet per minute;}$$

therefore, the slip, in accordance with rule given in Art. **1909**, is

$$\frac{214 - 167.112}{214} = .2191 = 21.91 \text{ per cent.} \quad \text{Ans.}$$

(1034) Applying formula **160**, Art. **1922**, and substituting,

$$D = \frac{835.5 \text{ } G \text{ } h}{W} = \frac{835.5 \times 4,000,000 \times 125}{7,460} = 55,998,660 \text{ ft.-lb.} \quad \text{Ans.}$$

(1035) See Art. **1862**.

(1036) (a) The number of gallons discharged per minute is  $\frac{70,000}{60} = 1,166\frac{2}{3}$ ; therefore, applying formula **158**, Art. **1921**, and substituting,

$$d_1 = .35 \sqrt{G} = .35 \sqrt{1,166\frac{2}{3}} = 11.955, \text{ say } 12 \text{ in.} \quad \text{Ans.}$$

(b) Applying formula **159**, Art. **1921**, and substituting,

$$d_2 = .25 \sqrt{G} = .25 \sqrt{1,166\frac{2}{3}} = 8.539, \text{ say } 8\frac{1}{2} \text{ in.} \quad \text{Ans.}$$

(1037) Applying formula **154**, Art. **1918**, and substituting,

$$H = .00038 \text{ } G \text{ } h = .00038 \times \frac{100,000}{60} \times 480 = 304 \text{ H. P.} \quad \text{Ans.}$$

(1038) (a) and (b) See Art. 1921.

(c) See Art. 1877.

(d) See Art. 1920.

(1039) Applying formula 153, Art. 1917, and substituting,

$$G = .03264 d^2 S = .03264 \times 15^2 \times 95 = 697.68 \text{ gal. per min.} \\ = 697.68 \times 60 = 41,860.8 \text{ gal. per hr. Ans.}$$

(1040) (a) The area of an 18-inch cylinder is

$$\frac{.7854 \times 18^2}{144} = 1.767 \text{ sq. ft.}$$

The total plunger displacement of the two pumps for the 10 hours was

$$1.767 \times 2 \times 2 \times 2\frac{1}{2} \times 12,480 = 220,521.6 \text{ cu. ft. Ans.}$$

(b) The plunger displacement in gallons for the 10 hours was  $220,521.6 \times 7.48 = 1,649,502$  gallons, nearly; therefore, the slip was

$$\frac{1,649,502 - 1,575,521}{1,649,502} = .04485 = 4.485 \text{ per cent. Ans.}$$

(c) The pressure corresponding to the vacuum in the suction-pipe is  $p = \frac{9.25}{2.037} = 4.54$  pounds; and the pressure corresponding to the difference in level of the centers of the vacuum gauge and the pressure gauge is  $s = 10.75 \times .434 = 4.666$  pounds.

Applying formula 161, Art. 1924, and substituting, the total number of foot-pounds of work is

$$W = 2 [1.767 \times 144 \times (108 + 4.54 + 4.666) \times 2.5 \times 2 \times 12,480] = 3,721,889,469.5 \text{ foot-pounds.}$$

Applying formula 162, Art. 1924, and substituting,

$$D = \frac{W}{H} \times 1,000,000 = \frac{3,721,889,469.5}{39,177,800} \times 1,000,000 = 95,000,000 \text{ ft.-lb. nearly. Ans.}$$

(1041) (a) See Art. 1925.

(b) See Art. 1932.

(c) See Art. 1956.

(1042) (a) See Art. 1938.

(b) See Art. 1942.

(1043) See Art. 1944.

(1044) See Art. 1946.

(1045) See Art. 1945.

(1046) See Art. 1966.

(1047) Applying formula 163, Art. 1969, and remembering that since the ram is horizontal its weight does not affect the pressure,

$$P = .7854 D^2 p \left(1 - \frac{F}{100}\right) = .7854 \times 8^2 \times 3,500 \left(1 - \frac{2.5}{100}\right) = 171,531.36 \text{ lb. Ans.}$$

(1048) See Art. 1939.

(1049) Applying formula 165, Art. 1971, and substituting,

$$D = \sqrt{\frac{P}{.7854 p \left(1 - \frac{F}{100}\right)}} = \sqrt{\frac{125,000}{.7854 \times 2,800 \times .985}} = 7.596, \text{ say } 7\frac{5}{8} \text{ in. Ans.}$$

(1050) Applying formula 163, Art. 1969, and substituting,

$$P = .7854 D^2 p \left(1 - \frac{F}{100}\right) = .7854 \times 6^2 \times 1,200 \times .99 = 33,590 \text{ lb. Ans.}$$

(1051) Applying formula 172, Art. 1977, and substituting,

$$D_1 = 1.128 \sqrt{\frac{V}{S}} = 1.128 \sqrt{\frac{10}{9}} = 1.189 \text{ ft., say } 14\frac{1}{4} \text{ in. Ans.}$$

(1052) Applying formula 169, Art. 1974, and substituting,

$$W_2 = .7854 D_1^2 p - W_1 = .7854 \times 16^2 \times 3,000 - 5,350 = 597,837 \text{ lb. Ans.}$$



(1053) (a) Applying formula **167**, Art. **1973**, and substituting,

$$p_1 = \frac{W_1 + W_2}{.7854 D_1^2 \left(1 - \frac{F}{100}\right)} = \frac{5,350 + 597,837}{.7854 \times 16^2 \times .9945} =$$

3,016.6 lb. per sq. in. Ans.

(b) Applying formula **168**, Art. **1973**, and substituting,

$$p_2 = \frac{W_1 + W_2}{.7854 D_1^2 \left(1 + \frac{F}{100}\right)} = \frac{5,350 + 597,837}{.7854 \times 16^2 \times 1.0055} =$$

2,983.56 lb. per sq. in. Ans.

(1054) Applying formula **165**, Art. **1971**, and substituting,

$$D = \sqrt{\frac{P + W}{.7854 p \left(1 - \frac{F}{100}\right)}} = \sqrt{\frac{15,000 + 3,240}{.7854 \times 500 \times .9925}} =$$

6.841, say 7 in. Ans.

(1055) Applying formula **164**, Art. **1970**, and substituting,

$$p = \frac{P + W}{.7854 D^2 \left(1 - \frac{F}{100}\right)} = \frac{52,000}{.7854 \times 8^2 \times .98} = 1,055.6,$$

or 1,056 lb. per sq. in., nearly. Ans.

(1056) See Art. **1958**.

(1057) See Art. **1963**.

(1058) See Art. **1949**.



# WATER SUPPLY AND DISTRIBUTION.

(QUESTIONS 1059-1118.)

(1059) Wholesomeness, abundance, good pressure, and cheapness. Art. 1979.

(1060) (a) Those of the typhoid and typhoid malarial classes. (b) During the visitation of epidemics, such as cholera and yellow fever. Art. 1980.

(1061) No; it is only one of a group of data from which intelligent inferences may be drawn. Art. 1981.

(1062) (a) It should be clear, colorless, tasteless, odorless, and sufficiently soft. (b) Contamination by even an infinitesimal portion of the sewage emanating from an infected district. Art. 1982.

(1063) Sewage. Art. 1983.

(1064) The positive knowledge that it has or has not been so contaminated. All other knowledge, however derived, whether by chemical analysis or otherwise, merely arouses or allays suspicion, but gives us no certainty, one way or the other, unless in extreme cases of pollution. Art. 1983.

(1065) (a) Sewage contamination. (b) Because it is an important constituent of human urine, which, in turn, is a principal element of sewage. (c) 3 to 10 parts by weight per million. Art. 1984.

(1066) Wanklyn's albuminoid ammonia process, and the moist-combustion process. Arts. 1986 and 1987.

(1067) (a) When it yields also more than 0.05 part of albuminoid ammonia per million. Art. 1986. (b) Under 0.10 part per million. Art. 1986.

(1068) (a) By the oxidation of its impurities. (b) The nitrites contained in sewage, upon being oxidized, are converted into nitrates. Nitrites arouse suspicion by indicating possible previous sewage contamination, and when found in large quantities in a water, unless their presence can be satisfactorily accounted for, often lead to its rejection as a potable supply, but authorities differ regarding the interpretation of the presence of this constituent. Art. **1989.**

(1069) (a) By the soap method, using a standard saponaceous solution, and noting the number of parts of water necessary to produce a "lather" with a given quantity of the solution. (b) 50 for soft, 150 for hard. Art. **1992.**

(1070) (a) 100 gallons. (b) By means of tanks in the houses or establishments supplied, or by introducing a short length of very small pipe in the service pipes. (c) A separate high service, using different mains. (d) Fire. Arts. **1995 to 1997.**

(1071) (a) By the general use of meters. (b) The Venturi meter. Art. **1999.**

(1072) (a) The ocean, and all large exposed water surfaces, but chiefly the first named. (b) Evaporation and rainfall. Arts. **2000, etc.**

(1073) Part runs off the surface of the ground to the most accessible stream or watercourse, and part soaks into the ground. Arts. **2001 and 2002.**

(1074) As a great storage reservoir. Art. **2003.**

(1075) Surface and ground water. Arts. **2004 to 2006.**

(1076) All water taken from lakes, ponds, streams, and rivers. Art. **2005.**

(1077) All water taken from beneath the surface of the earth by wells, deep or shallow, and springs, when taken near the point at which they issue from the ground. Art. **2006.**

(1078) Surface water is generally softer, and is more subject to contamination than deep-well water. Ground water is apt to be harder, from impregnation with earthy salts, and in deep wells the temperature is frequently high. Shallow-well water is apt to reunite nearly all the bad qualities of both sources except the high temperature. Springs, on the contrary, frequently furnish the very best class of water, but the supply drawn from this source is usually limited. Arts. **2005** and **2006**.

(1079) By pumping directly from some large river into a distributing reservoir, or, more rarely, by gravity from the same source; by damming some smaller stream, thus forming a reservoir from which water can be taken by pumping, if below the level of the town to be supplied, or by gravity, if it has been possible to erect the dam at a sufficiently high elevation. These two methods relate to surface water. The supply might also be drawn from the ground, in which case the means employed would be driven wells (discarding shallow wells as not suitable for a large public supply), galleries, or the collecting of springs in suitable basins. Art. **2007**.

(1080) 1st. By gauging the flow of the stream. 2d. By ascertaining the area of its water-shed and the yearly precipitation or rainfall. Arts. **2011** and **2012**.

(1081) From 40% to 50%. One million gallons per square mile of drainage area per 24 hours is a convenient approximate rule for the available supply from a given stream in these States. Arts. **2012** and **2013**.

(1082) To equalize the discharge of the stream, converting a yearly average into a daily one. Art. **2016**.

(1083) Forty per cent. of 33 is 13.2 inches available yearly rainfall. One inch over a square mile gives 17,378,743 U. S. gallons; therefore, 13.2 inches give 229,399,407 gallons per square mile. There are  $8\frac{1}{2}$  square miles; consequently, in round numbers, the yearly yield of the stream is 1,950 millions.

The yearly consumption is  $3 \times 365 = 1,095$  million gallons. Then, by the formula (see note, Art. **2017**),  $\frac{(1,095)^2}{1,950} = 614.88$  million gallons. This is a little over 200 days' supply.

(1084) Upon the existence of a water-bearing stratum, lying between two impermeable ones. When the upper impermeable stratum is pierced, and a water-tight tube in-

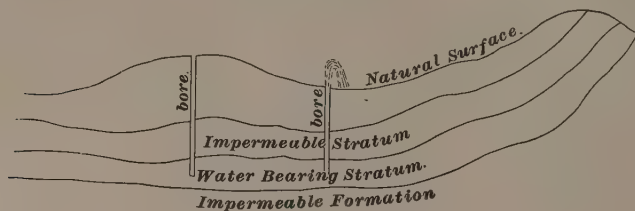


FIG. 77.

serted in the bore, the water rises to a greater or lesser height in the tube, as shown in Fig. 77. See Art. **2020**.

(1085) The difficulty consists in the necessity of lifting the water from each separate well to a common recipient, from which it can be pumped. Art. **2022**.

(1086) Springs constitute a kind of natural flowing or artesian wells. As already stated, in answer to question 1078, they are apt to be of low temperature, but in this country have been seldom utilized for public supplies; owing to their rarity, and also, perhaps, because attention has not been sufficiently directed to this source of supply. The best examples of water supplies on a large scale drawn from springs are to be found in the water-works system of Paris, France. In developing springs, the greatest care is necessary to avoid diverting them to other outlets. Art. **2023**.

(1087) By exposure to the atmosphere, by which a very slow oxidation takes place of the organic impurities. The action is very slight, and by no means adequate to purify

a water containing any considerable amount of such impurities. Art. **2025**.

(1088) (*a*) Filtration, either natural or artificial. (*b*) By nitrification. (*c*) By infiltration through soil, and the agency of a bacillus. See Art. **2026**.

(1089) (*a*) See Art. **2028** and Fig. 649. (*b*) The characteristic action of the filter-bed is the formation of a film, deposited by the water itself, and constituting the habitat of the bacillus referred to in answer to question 1088. (*c*) When the water treated is distinctly turbid. One day's supply. (*d*) When the mean January temperature is below freezing. (*e*) One and four-tenth acres always in use, besides the area laid off for cleaning. Arts. **2028** to **2033**.

(1090) (*a*) The prevention of many water-borne diseases, notably cholera and typhoid fever. (*b*) Those of all large rivers and all suspected waters when the death-rate from typhoid fever of the community using them becomes excessive. Art. **2035**.

(1091) The substitution of a coagulant, ordinarily common alum, for the natural sedimentary film already mentioned in the answer to question 1089. (*b*) Art. **2036**.

(1092) By damming a stream. Art. **2040**.

(1093) To prevent vegetable growth, chiefly that of the algæ. Art. **2041**.

(1094) Sufficient capacity and elevation. Art. **2042**.

(1095) The use of a second stationary barometer and thermometer at some point of which the elevation is known, or which may be used as a convenient datum, which should be observed at stated intervals. When barometric and thermometric readings are taken by the explorer, he should note the time at which they are taken, so as to compare his

readings with those of the observer at the stationary instruments. Art. 2043.

(1096) (a) By a contour map, made from a careful cross-sectioning of the entire probable site of the dam. (b) The establishing of permanent monuments. Arts. 2043 and 2044.

(1097) When a solid rock foundation for bottom and sides of dam can be secured. Art. 2045.

(1098) (a) A substantial center wall, carried down to a suitable depth. (b) To furnish an impermeable cut-off against any percolation which might penetrate the dam, and also a means of connecting all the appliances, pipes, culverts, etc., destined to establish communication between the inside and outside of the reservoir, without danger of producing leaks. Art. 2046.

(1099) See Art. 2046 and Fig. 78.

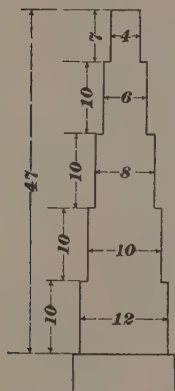


FIG. 78.

(1100) (a) Two and a half horizontal to one vertical. (b) Three and a half horizontal to one vertical. (c) Equal to the height of the spillway above the bottom of the stream across which the dam is built. Art. 2047.

(1101) It should be thoroughly cleared and grubbed, and all roots and stumps removed. Art. 2047.

(1102) Applying formula 173, Art. 2048, we have the length  $L = 20 \sqrt{18} = 85$  feet, nearly. Ans.

By formula 174, we have the depth

$$D = \sqrt[3]{\frac{47^2 \times 18}{16}} + C = 2.1 \text{ ft.} + C. \text{ Ans.}$$

(1103) (a) For dams not exceeding 15 ft., a vertical or slightly battering face may be given, with a substantial



apron to receive the shock of the falling water. For higher dams, either a curved surface or a series of steps. (b) It is more economical than the curved form, which involves much stone-cutting, and it is very effectual in destroying the momentum of the falling water. Art. **2052**.

(1104) Simplicity, efficiency, and strength. Art. **2054**.

(1105) To accommodate the sliding sluice-gates, and the grooves for the stop-plank and screens. Arts. **2054** and **2055**.

(1106) Sluice-gates and stop-cocks. Arts. **2054** and **2055**.

(1107) To maintain a uniform head near the point of consumption; to afford a convenient place for the more complicated appliances for the control of the water distributed to different parts of the town, and to furnish a small reserve supply of water in the immediate vicinity of the town, to provide against any accidental temporary interruption of the pumps. Art. **2057**.

(1108) (a) The summit of a conveniently situated rounded hill, the ground sloping away in all directions from it. (b) In excavation, with concrete bottom and masonry side walls. Arts. **2058** and **2059**.

(1109) There are several ways in which this can be done; probably the simplest and best is by closing the end of the chamber *C*, and putting in sluice-gates at different levels, as shown in Fig. 79.

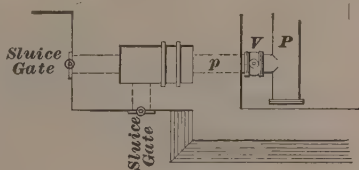


FIG. 79.

(1110) That they have a sufficient cross-section to insure against crushing under the weight of the cover. Art. **2061**.

(1111) That the horizontal thrust of the water is always equal to  $31.25 H^2$ ,  $H$  being the head of water sustained by the dam; and that the moment of the same, around the outer toe of the dam, is  $10.42 H^3$ . Art. 2063.

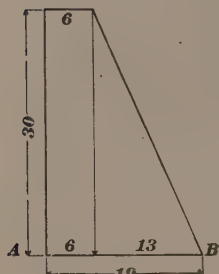


FIG. 80.

(1112) (a) By the moment of the thrust, as given in previous answers. (b) By its moment of resistance around its outer toe. Arts. 2064 and 2065.

(1113) The section of wall being as shown in Fig. 80, and the density being 125, the resisting moment about the outer toe  $B$  is

$$\begin{array}{r}
 180 \times 16 = 2880 \\
 \frac{30 \times 13}{2} \times \frac{2}{3} \times 13 = 13^2 \times 10 = 1690 \\
 \hline
 4570 \\
 125 \\
 \hline
 22850 \\
 9140 \\
 4570 \\
 \hline
 571250
 \end{array}$$

The overturning moment about the same point is

$$10.42 \times 30^3 = 281,340.$$

$$\text{Then, } \therefore \frac{57,125}{28,134} = 2.03 = \text{factor of safety.}$$

Inserting data in formula 182, Art. 2068,

$$19 = \frac{1}{2} \sqrt{900 C + 108} - 3.$$

$$22^2 = \frac{1}{4} (900 C + 108).$$

$$484 = 225 C + 27.$$

$$C = \frac{457}{225} = 2.03 = \text{factor of safety, as above.}$$

(1114) Resisting moment of plumb wall, neglecting density, is

$$\frac{27 \times 18 \times 18}{2} = 4,374.$$

Resisting moment of trapezoidal wall, as per Fig. 81, is

$$27 \times 6 \times 15 = 2,430$$

$$\frac{27 \times 12}{2} \times \frac{2}{3} \times 12 = 1,296$$

$$3,726$$

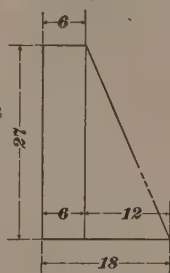


FIG. 81.

Then, 
$$\frac{\text{Trapezoidal}}{\text{Plumb}} = \frac{3,726}{4,374} = 0.85.$$

The resistance to sliding of plumb wall, neglecting coefficient of friction, is

$$27 \times 18.$$

That of trapezoidal wall is

$$27 \left( \frac{6 + 18}{2} \right) = 27 \times 12.$$

Hence, 
$$\frac{\text{Trapezoidal}}{\text{Plumb}} = \frac{12}{18} = 0.67.$$

(1115) Crushing of the material. Art. 2071.

(1116) Taking moments about the toe  $B$ , the resultant of the weight of the whole mass above  $A B$  when the reservoir is empty is obtained thus:

|          |   |       |   |           |        |
|----------|---|-------|---|-----------|--------|
| 300      | × | 56.67 | = | 17001.    |        |
| 3675     | × | 46.67 | = | 171512.25 |        |
| 337.5    | × | 73    | = | 24637.50  |        |
| 4312.5   |   |       |   | 213150.75 | 4312.5 |
| 144      |   |       |   | 172500    | 49.43  |
| 17250.0  |   |       |   | 40650.7   |        |
| 172500   |   |       |   | 38812.5   |        |
| 43125    |   |       |   | 1838.25   |        |
| 621000.0 |   |       |   | 1725.00   |        |
|          |   |       |   | 113.250   |        |
|          |   |       |   | 129.375   |        |

Then  $79 - 49.43 = 29.57$ ; and we get the diagram, Fig. 82.

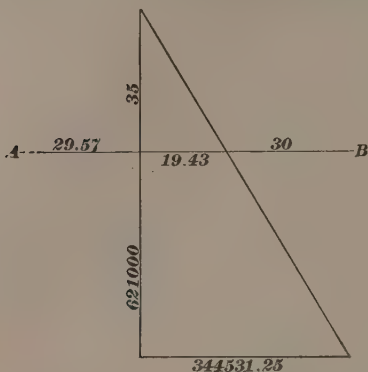


FIG. 82.

Proceeding as in general example (see Art. 2075), we get, max. stress in segment

$$A = \frac{621,000 \times 49.43}{79 \times 29.57} = 13,140 \text{ lb.};$$

max. stress in segment

$$B = \frac{621,000 \times 49}{79 \times 30} = 12,839 \text{ lb.}$$

(1117) The resisting

moment of the dam about

the outer toe  $B$  is (utilizing calculations already made in previous answer)

$$213,150.75 \times 144 = 30,693,708 \text{ ft.-lb.}$$

The overturning moment, due to the thrust of the water, is

$$10.42 \times 105^3 = 12,062,452.50 \text{ ft.-lb.}$$

Then, factor of safety =

$$\frac{30,693,708}{12,062,453} = 2.54.$$

It would not be wise, therefore, to reduce the base, although it might be safely done as against crushing, because the above factor of safety against overturning is not too great.

(1118) That dams of less than say 125 ft. in height must be calculated to resist overturning as well as crushing of the material.

# WATER SUPPLY AND DISTRIBUTION.

(QUESTIONS 1119-1143.)

---

(1119) The surface of water, when at rest, is level. No motion, or flow, is possible unless the surface assumes a sloping line. *The hydraulic grade-line is the grade assumed by the surface of flowing water.* In an open canal, this grade is easily determined; in a pipe-line of uniform diameter and character, it is the imaginary line joining the upper and lower extremities of the pipe; or, if the pipe connects two reservoirs, then it is the line joining the two water surfaces. If the line is composed of pipes of different diameters, or if there are branches leading to or from the pipe-line, then the hydraulic grade becomes a broken line, and it is located by determining the *piezometric height* at each point where any change occurs in the character of the line. Art. 2085.

(1120) A reducer, in order to diminish the resistance to entry, and consequent diminution of velocity, due to square or abrupt angles at the point of entrance, or at the change of diameters of the connecting pipes.

(1121) (a) A vertical tube, usually an imaginary one, open at the top, and supposed to be inserted in a pipe through which water flows, in such a way that the water in the main pipe may freely rise and fall in it. (b) The height to which the flowing water does or may rise in a piezometric tube inserted, or supposed to be inserted, at the given point. (c) A pressure-gauge; the recorded pressure can be converted into the piezometric height, expressed in feet, by multiplying the pounds per square inch by 2.304. Arts. 2085 to 2087.

(1122) To assure ourselves that the pipe-line does not rise above it at any point. Art. 2087.

(1123) Direct experiment. Arts. 2088 and 2089.

(1124) One of which the length is at least one thousand diameters. Art. 2092.

(1125) See formula 186, Art. 2092.

(1126) See formula 188, Art. 2092.

(1127) (a) See formula 193, Art. 2094. (b) See formula 196, Art. 2094.

(1128)  $13.5 \times 1.4 = 18.90$  cu. ft. per sec. Art. 2095.

(1129) (a)  $Q = \sqrt{1 \times 1^5} = 1$  cu. ft. per sec.

(b) Because it enables us to deduce, readily, the corresponding elements of any other pipe, by means of the relation given in formula 205, Art. 2097, which is sometimes a convenience.

(1130) (a) Here we have:  $D = 1$ ;  $H = 1.3725$ ;  $L = 1,372.5$ , and, by calculation,  $Q = 1$ . Also, we have:  $D' = 1.5$ ;  $H' = 4.6$ ,  $L' = 2,300$ .  $Q'$  is required. Inserting these data in formula 206, Art. 2097,

$$\frac{1^2 \times 1,372.5 \times \overline{1.5^5} \times 4.6}{Q'^2 \times 2,300 \times 1^5 \times 1.3725} = 1;$$

which reduces to  $\frac{2 \times 7.6}{Q'^2} = 1;$

whence,  $Q' = 3.90$  cu. ft. per second. Ans.

(b)  $Q = \sqrt{\frac{7.6 \times 4.6 \times 1,000}{2,300}} = 3.90$  cu. ft. per second. Ans.

(1131) From formula 191, Art. 2094,

$$3.42 = \sqrt{\frac{75,000 D^5}{17,600}}.$$

Hence,  $11.70 = \frac{75 D^5}{17.6};$

and,  $D = \sqrt[5]{2.744}.$

$$D = 1.224 \text{ ft.}$$

Or say 16 inches. Ans.

(1132) Let us make elevation of the extremity of pipe (300 in the question) equal 0. Then, elevation of extremity of 6-inch pipe is 20, that of 8-inch pipe 90, and that of reservoir 200. We then represent all on a sketch, drawn to scale, on cross-section paper. We will adopt the approximate method (Art. 2103), and assume a piezometric height at point of embranchment of 6-inch pipe = 30 ft. Then, quantity  $Q$  discharged at the extremity of 16-inch pipe is

$$Q = \sqrt{\frac{30,000}{3,000}} \times \left(\frac{4}{3}\right)^5 = 6.49 \text{ cu. ft.}$$

Also, quantity  $Q'$  discharged by 6-inch pipe is

$$Q' = \sqrt{10 \times 0.5^5} = 0.56.$$

Total discharge from both =  $Q + Q' = 7.05$ .

We now find the piezometric height, above elevation 30 at the embranchment of the 8-inch pipe, necessary to force this amount of water through 5,000 ft. of 16-inch pipe, thus :

$$h = \frac{49.70}{\frac{1,024}{243}} = 11.8.$$

This is the rise per 1,000; hence, total rise =  $11.8 \times 5 = 59$  ft.

We now test this value by adding it to the piezometric height 30, which gives  $59 + 30 = 89$  ft.

As the elevation of the extremity of the 8-inch pipe is 90, it is clear that this elevation is too low to produce a flow in the 8-inch pipe. It is possible, however, that *no* water can flow from this pipe, on account of the height of its point of discharge. To test this, we carry the rise of 11.8 ft. per 1,000 through to the reservoir, which is distant 12,000 ft. from the point of embranchment of 6-inch pipe. This gives  $11.8 \times 12 = 141.6$  ft., which, added to the assumed piezometric height, 30 ft., gives 171.6 ft. But the elevation of the reservoir is 200 ft., so the assumed height of 30 ft. is not high enough, and if raised sufficiently to reach the reservoir there would be a discharge through the 8-inch pipe.

We, therefore, try another piezometric height, 33 ft., which gives

$$Q = \sqrt{\frac{33}{3} \times \left(\frac{4}{3}\right)^5} = 6.77 \text{ cu. ft.}$$

Also, the discharge through 1,000 ft. of 6-inch pipe, the fall being  $33 - 20 = 13$  ft. per 1,000, is

$$Q' = \sqrt{13 \times 0.5^5} = 0.64 \text{ cu. ft.}$$

Then,  $Q + Q' = 7.41$  cu. ft.

For the 5,000 ft. of 16-inch pipe, the necessary rise per 1,000 will be

$$h = \frac{7.41^2}{\frac{1,024}{243}} = 13.03 \text{ ft.}$$

The total rise is, therefore,  $13.03 \times 5 = 65.15$  ft.

This being added to the assumed height of 33 ft. gives 98.15 ft. for the piezometric height at the junction of the 8-inch pipe with the 16-inch.

The 8-inch pipe is 1,200 ft. long, and the elevation of its extremity is 90 ft. Hence, the rise per 1,000,  $h$ , is

$$h = \frac{98.15 - 90}{1.2} = 6.8.$$

Then the quantity  $Q''$  which it discharges is

$$Q'' = \sqrt{6.8 \times \left(\frac{2}{3}\right)^5} = .95 \text{ cu. ft.}$$

The total discharge is, therefore,  $6.77 + 0.64 + 0.95 = 8.36$  cu. ft.

We now want the rise per 1,000 to discharge this through the remaining 7,000 ft. of 16-inch pipe which intervenes between the 8-inch pipe and the reservoir.

$$\text{We have} \quad h = \frac{8.36^2}{\frac{1,024}{243}} = 16.59 \text{ ft.}$$

On 7,000 ft. this amounts to  $16.59 \times 7 = 116.13$  ft. This, added to 98.15, gives 214.28 ft. As the elevation of the reservoir is only 200 ft., we have taken our first assumed height too high. Our first assumption, 30, was too low, the



present one, 33, is too high, so the true value evidently lies within narrow limits.

An inspection of the above results shows that an addition of 3 ft. to the first assumed piezometric height made a difference of  $214.3 - 171.6 = 42.7$  ft. in the required elevation at the reservoir.

The difference for 1 ft. is, therefore,  $42.7 \div 3 = 14.2$  ft.; consequently, if we reduce the assumed piezometric height from 33 ft. to 32 ft., the required height at the reservoir will be reduced to about 200 ft., which is the value it must have to agree with the data.

Using 32 ft. as the first assumed piezometric height, and calculating as before, we have

$$\begin{aligned} Q &= \sqrt{\frac{3.2}{3} \times \left(\frac{4}{3}\right)^5} = 6.7 \\ Q' &= \sqrt{12 \times .5^5} = .6 \\ Q + Q' &= 7.3 \text{ cu. ft.} \end{aligned}$$

Fall per 1,000 in 5,000 ft. of 16-inch pipe,

$$h = \frac{7.3^2}{\frac{1,024}{243}} = 12.64 \text{ ft.}$$

$$12.64 \times 5 + 32 = 95.2.$$

$$Q'' = \sqrt{\frac{5.2}{1.2} \times \left(\frac{2}{3}\right)^5} = .76 \text{ cu. ft.}$$

$$Q + Q' + Q'' = 6.7 + .6 + .76 = 8.06 \text{ cu. ft.}$$

Fall per 1,000 in 7,000 ft. of 16-inch pipe,

$$h = \frac{8.06^2}{\frac{1,024}{243}} = 15.41 \text{ ft.}$$

$$15.41 \times 7 = 107.87 \text{ ft.,}$$

which, added to 95.2, gives 203.07 ft., as against 200. This, in practice, would be a satisfactory result, and the calculation would be carried no further, because, at best, all these calculations are but approximations, indicating the probable truth.

(1133) Applying formula 209, Art. 2111, we have

$$\frac{4,000}{D^5} = \frac{1,000}{(\frac{2}{3})^5} + \frac{700}{1} + \frac{800}{(2)^5} + \frac{1,500}{(\frac{1}{2})^5}.$$

$$\frac{4,000}{D^5} = \frac{243,000}{32} + 700 + \frac{800}{32} + 48,000.$$

$$\frac{128,000}{D^5} = 243,000 + 22,400 + 800 + 1,536,000.$$

$$D^5 = \frac{128,000}{1,802,200} = 0.071.$$

$$\text{Log } D^5 = \bar{2}.851258.$$

$$\text{Log } D = \bar{1}.770251; D = 0.589 \text{ ft.} = 7 + \text{inches.} \quad \text{Ans.}$$

(1134) See Art. 2106. By making a sketch on section paper, it will be evident that the two upper reservoirs feed into the lowest one; also, that the piezometric height at the junction of the 12-inch pipe with the 18-inch will be about 380. Calling the elevation of the lowest reservoir 0, gives elevation highest reservoir 250, elevation of intermediate reservoir 150, and piezometric height 130.

Then, quantity received in lowest reservoir is

$$Q = \sqrt{37.14 \times 7.6} = 16.80 \text{ cu. ft.}$$

Quantity delivered by highest reservoir,

$$Q' = \sqrt{34.29 \times 7.6} = 16.10 \text{ cu. ft.}$$

Quantity delivered by intermediate reservoir,

$$Q'' = \sqrt{4.44} = 2.11 \text{ cu. ft.}$$

$Q' + Q'' = 18.21 \text{ cu. ft.}$ , total received by lowest reservoir. Hence, the assumed piezometric height of 130 is a little too low. We try 135.

$$\text{Then, } Q = \sqrt{38.57 \times 7.6} = 17.12 \text{ cu. ft.}$$

$$Q' = \sqrt{32.86 \times 7.6} = 15.80$$

$$Q'' = \sqrt{3.33} = 1.82$$

$$\text{————— } 17.62 \text{ cu. ft.}$$

This is a very satisfactory check, and we carry the calculation no further.

(1135) See Art. **2113**. Area of pipe, 3.1416 sq. ft.  
 Velocity necessary to produce given flow,  $\frac{23}{3.1416} = 7.32$  ft.  
 per second. Then,

$$\text{Frictional height} = \frac{(23)^2 \times 30}{32 \times 1,000} = 0.496$$

$$\text{Velocity and entrance heads} = \frac{3 \times (7.32)^2}{4 \times 32.16} = 1.249$$


---

1.745 ft.

This would bring the top of the pipe so near the surface of the water that it could be scarcely considered a good arrangement, because vortexes might be produced. It would be better to use a somewhat smaller pipe, say 20 or 22 inches, with a deeper submersion.

(1136) Substituting data in formula **210**, Art. **2117**,

$$350 = \frac{7 H}{8.8}.$$

$H = 440$ . Subtracting the height of reservoir above pump,  $440 - 360 = 80$  ft. The distance being 3,000 ft., we have

$$h = \frac{80}{3} = 27, \text{ nearly.}$$

Then,  $D = \sqrt[5]{\frac{4.9}{27}} = 1.127$  ft., or say 14 inches.

(1137) Daily supply,  $\frac{3,000,000}{7.48} = 401,070$  cu. ft. per 24 hours. If consumed in 10 hours, this gives 40,107 cu. ft. per hour, or 11.14 per sec., for which discharge the mains should be calculated. See Art. **2121**.

$$(1138) \frac{60,000}{5,280} = 11.36 = \text{distance in miles.}$$

Head, 250 ft. Then, thickness of pipe from formula **214**, Art. **2128**, is

$$T = 0.00006 \times 250 \times 10 + 0.0133 \times 10 + 0.296 = 0.579 \text{ inch.}$$

Then, from formula **213**, Art. **2127**,

$$P = 25 \times 11.36 \times 10.579 \times 0.579 = 1,740 \text{ long tons. Ans.}$$

(1139) Air-cocks at the summits and blow-offs at the valleys, or lowest points. Arts. 2133 and 2134.

(1140) To start with all air-cocks and blow-offs open and fill very gradually, closing blow-offs and air-cocks successively, as described in Art. 2137.

(1141) A distributing reservoir, containing a week's supply, situated at such an elevation as to give an efficient pressure throughout the town, which distributing reservoir is fed from a storage reservoir by gravity. Art. 2138.

(1142)  $42 \times 1.05 = 44.10$  inches.  $42 \times 1.10 = 46.20$  inches. 45 inches would in ordinary cases be the proper diameter. Art. 2141.

(1143) Applying the rules of Arts. 780 to 785, we find the water section  $S$  and the wetted perimeter  $W$  as follows:

The water section is found by dividing the section of the aqueduct into three parts: a semicircle whose diameter is  $3.71 \times 2 = 7.42$  feet; a segment whose radius is 8 feet; rise, .75 foot, and chord, 6.75 feet; and the trapezoid included between the semicircle and the segment.

The water section included in the semicircle is equal to the area of the semicircle minus the area of the segment whose rise is 1.12 feet. The area of the semicircle is

$$\frac{7.42^2 \times .7854}{2} = 21.62 \text{ square feet.}$$

In order to find the area of the segment, we first find the angle included by its arc. The cosine of one-half of the arc is

$$\frac{3.71 - 1.12}{3.71} = .69811;$$

from the table of sines and cosines the corresponding angle is found to be  $45^\circ 43\frac{1}{2}'$ ; therefore, the angle included by the arc is  $2 \times 45^\circ 43\frac{1}{2}' = 91^\circ 27' = 91.45^\circ$ . The area of the included sector is

$$\frac{43.24 \times 91.45}{360} = 10.98 \text{ square feet.}$$

The length of chord of the arc is

$$2\sqrt{3.71^2 - 2.56^2} = 5.312 \text{ feet,}$$

and the area of the triangle included between this chord and the radii to its extremities is

$$\frac{5.312 \times 2.59}{2} = 6.88 \text{ square feet.}$$

The area of the segment is, therefore,  $10.98 - 6.88 = 4.10$  square feet, and the area of the water section included in the semicircle is  $21.62 - 4.10 = 17.52$  square feet.

To find the area of the lower segment, we first find the angle included by its arc. The sine of one-half of the angle is  $\frac{3.375}{8} = .42188$ . The corresponding angle is  $24^\circ 57'$ , nearly; therefore, the angle included by the arc of the segment is  $49^\circ 54' = 49.9^\circ$ . The area of a circle whose radius is 8 feet is  $16^2 \times .7854 = 201.06$  feet. The area of the sector is, therefore,

$$\frac{201.06 \times 49.9}{360} = 27.869 \text{ square feet;}$$

the area of the triangle included between the chord and the radii to its extremity is

$$\frac{6.75 \times 7.25}{2} = 24.469 \text{ square feet,}$$

leaving  $27.869 - 24.469 = 3.40$  square feet as the area of the segment.

The area of the trapezoid included between the semicircle and the lower segment is

$$\frac{7.42 + 6.75}{2} \times 4 = 28.34 \text{ square feet.}$$

The total area of the water surface is, therefore,

$$S = 17.52 + 3.40 + 28.34 = 49.26 \text{ square feet.}$$

The perimeter of the semicircle is

$\frac{3.1416 \times 7.42}{2} = 11.655$  feet, and the length of the arc not in contact with the water is

$$\frac{23.31 \times 91.45}{360} = 5.921 \text{ feet.}$$

This gives us  $11.655 - 5.921 = 5.734$  feet as the wetted perimeter included in the semicircle. The circumference of a circle whose diameter is 16 feet is  $16 \times 3.1416 = 50.265$  feet; therefore, the wetted perimeter included by the lower segment is

$$\frac{50.265 \times 49.9}{360} = 6.967 \text{ feet.}$$

The wetted perimeter included by the trapezoid is  $2 \times 4 = 8$  feet, very nearly.

The total wetted perimeter is

$$WP = 5.921 + 6.967 + 8 = 20.888 \text{ feet.}$$

The mean hydraulic radius is

$$R = \frac{S}{WP} = \frac{49.26}{20.888} = 2.36, \text{ nearly.}$$

Applying formula **215**, Art. **2143**, we have

$$U = R \sqrt{\frac{100,000 I}{6.6 R + 0.46}} = 2.36 \sqrt{\frac{21}{16.036}} = 2.70 \text{ ft. per sec.}$$

Ans.

# IRRIGATION.

(QUESTIONS 1144-1217.)

---

(1144) It is still in its infancy, but constantly growing in importance and in scientific methods. (Art. 2147.)

(1145) Because plants require that the substances necessary for their growth should be presented to them in solution in water. They drink, and do not eat, their nourishment. (Art. 2148.)

(1146) By rainfall. (Art. 2149.)

(1147) East of the 97th meridian. (Art. 2149.)

(1148) A sufficient but not excessive quantity of water, supplied with regularity at certain stages of plant growth, depending upon the nature of the crop and its time of planting and harvesting. (Arts. 2149 and 2150.)

(1149) A proper public water supply requires to be so regulated and controlled that a certain daily quantity throughout the year shall be furnished. The answer to the previous question shows that for irrigation purposes the supply is intermittent, and is needed at certain seasons only. (Art. 2153.)

(1150) Artificial irrigation, when properly conducted, is superior to rainfall in that it can be supplied or withheld at will, according to the needs of the crops cultivated. (Arts. 2150 and 2151.)

(1151) From 40,000 to 100,000 cubic feet per acre per annum, or say sufficient to cover the area irrigated to a depth of from 1 to  $2\frac{1}{2}$  feet. (Art. 2152.)

(1152) Yes; because such favored regions are still subject to periods of drought at seasons when crops most need water. (Art. 2149.)

(1153) See Art. 2152.

(1154) Provided the water does not contain distinctly injurious substances, such as those favoring the production of alkali, quality is a matter of small moment. Indeed, water charged with organic matter, and even sewage, is thereby rendered more beneficial to plant growth than if perfectly pure. (Art. 2153.)

(1155) (a) Upwards of 40,000,000 acres. (b) \$450,000,000. (Art. 2154.)

(1156) A very important part. In many cases irrigation without underdrainage, either natural or artificial, would be an injury instead of a benefit. (Art. 2155.)

(1157) The presence of alkali is a serious detriment to the growth of crops, covering the surface of the ground with a hard efflorescent crust composed chiefly of salt, sal soda, and Glauber's salts, of which the sal soda, known as "black alkali," is the most pernicious. (Art. 2156.)

(1158) Thorough underdraining to prevent supersaturation of the soil, mulching, and the use of gypsum as a top dressing. Sometimes it can be washed off by flooding. (Arts. 2156 and 2157.)

(1159) No. It should be supplemented by all the other resources known to the agriculturist. Irrigation merely substitutes rainfall, leaving all the other requirements as before. (Art. 2158.)

(1160) (a) Surface and ground water. (b) Surface water, as used in irrigation, consists in the run-off of streams; ground water is all water derived from wells, deep or shallow. (Art. 2160.)

(1161) The quantity of water required, if the area to be irrigated is given; or the area that can be irrigated, if the amount of water disposable is given. (Art. 2160.)



(1162)  $23 \times 640 \times 175,000 = 2,576,000,000$  cu. ft. Ans.

(1163) (a) The run-off of a given area is the unabsorbed and unevaporated volume of rain falling upon such area, which finds its way to its brooks, streams, and rivers. (b) From 33% to 50%. (Art. 2160.)

(1164) Diameter of funnel,  $\frac{1.85}{16}$  inches; diameter of cylinder,  $\frac{1.31}{32}$ . Then the actual depth of rainfall is to depth of water in cylinder (3.17 inches) as the square of diameter of cylinder is to square of that of the funnel. Representing the desired depth of rainfall by  $x$ , the above proportion will be written:

$$x : 3.17 = \left(\frac{1.31}{32}\right)^2 : \left(\frac{1.85}{16}\right)^2.$$

Whence,  $x = 0.397$ .

That is, the rainfall was 0.397 inch for the  $7\frac{1}{3}$  hours, or 0.0541 inch per hour. Ans.

(1165) By means of a weir. (Art. 2163.)

(1166) Applying formula 217, Art. 2163, we have

$$Q = 3\frac{1}{2} \times 4.23 \times 1.73^{\frac{3}{2}} = 32.08 \text{ cu. ft. per sec.} \quad \text{Ans.}$$

(1167) All observations must be made with great care, and they should be repeated until it is certain they are as near correct as the conditions will allow. (Art. 2164.)

(1168) These difficulties consist in the fact that the evaporation from the surface of a large body of still water is different from that of the supplying stream. (Art. 2165.)

(1169) From 3 to 5 feet per annum. (Art. 2165.)

(1170) Generally, facilities for discharging large volumes of water during short periods of time are more necessary for the irrigation reservoir than for water supply. (Art. 2166.)

(1171) This sketch should be made according to the general features shown in Fig. 701, Art. 2167, carrying the cribs well down to the good foundation.

(1172)  $\frac{6}{5,280} = 0.001136 = \text{tangent of the angle of the slope.}$  The nearest number given in the table is 0.00116, corresponding to an angle of 4 minutes, which would be sufficiently close in such preliminary work.

(1173) The character of the material through which it runs, regarding its greater or less liability to cave in and wash, and the consequent admissible velocity. (Art. 2171.)

(1174) Gravity. (Art. 2172.)

(1175) See Art. 2173.

(1176) (a) Since the slope of the sides is  $1\frac{1}{2}$  horizontal to 1 vertical, the top width of the water section is  $8 + 2 \times 5 \times 1\frac{1}{2} = 23$  feet, and the length of each of the sloping sides is  $\sqrt{5^2 + 7\frac{1}{2}^2} = 9.01$  feet; the length of the wetted perimeter is, therefore,  $8 + 2 \times 9.01 = 26.02$  feet. Ans.

(b) The area of the water cross-section is  $\frac{23+8}{2} \times 5 = 77\frac{1}{2}$  square feet. Ans.

(c) The hydraulic radius is  $77.5 \div 26.02 = 2.98$  ft. Ans.

(d) The slope is  $s = \frac{7}{5,280} = .0013$ ; therefore, by applying formula 219, Art. 2177, we have the velocity of flow

$$v = \sqrt{\frac{100,000 \times 2.98^2 \times .0013}{9 \times 2.98 + 35}} = 4.32 \text{ ft. per sec.}$$

The discharge is, therefore,  $Q = av = 77.5 \times 4.32 = 334.8$  cu. ft. per sec. Ans.

(1177) Let  $x$  = depth of water. Then,  $2x$  = width of flume. The wetted perimeter will then be  $4x$ , and the area of the water cross-section  $2x^2$ . The hydraulic radius  $r = \frac{2x^2}{4x} = 0.5x$ . The slope is  $s = \frac{9}{5,280} = .0017$ . The dis-

charge is to be 100 cu. ft. per second. The mean velocity must then be

$$v = \frac{100}{2x^2} = \frac{50}{x^2}.$$

Inserting the data in formula **226**, Art. **2196**,

$$\frac{50}{x^2} = \sqrt{\frac{100,000 \times 0.25 x^2 \times 0.0017}{3.3x + 0.46}}.$$

Squaring both sides,

$$\frac{2,500}{x^4} = \frac{100,000 \times 0.25 x^2 \times 0.0017}{3.3x + 0.46}.$$

$$\frac{1}{x^4} = \frac{0.017 x^2}{3.3x + 0.46}.$$

$$0.017 x^6 - 3.3x = 0.46.$$

$$x^6 - 194x = 27.$$

Assuming a value of  $x = 3$ , the first number of the equation becomes

$$3^6 - 194 \times 3 = 729 - 582 = 147,$$

which is too large. Trying 2.9, we have for the value of the first number,

$$2.9^6 - 194 \times 2.9 = 594.8 - 562.6 = 32.2;$$

and 2.8 gives us

$$2.8^6 - 194 \times 2.8 = 481.9 - 543.2 = -61.3.$$

We therefore see that the true value is slightly less than 2.9. We will make the depth 3 feet, the width of the flume 6 feet, and check our work by computing the quantity that would be discharged by our flume. Substituting in formula **226**, Art. **2196**, we have, since the wetted perimeter is  $2 \times 3 + 6 = 12$  ft., the water cross-section 18 sq. ft., and the hydraulic radius  $18 \div 12 = 1.5$ .

$$v = \sqrt{\frac{100,000 \times 1.5^2 \times .0017}{6.6 \times 1.5 + .46}} = 6.07 \text{ ft. per second.}$$

The discharge, therefore, will be

$$18 \times 6.07 = 109.26 \text{ cu. ft. per sec.,}$$

which satisfies the required conditions.

(1178) The total weight of the water in the flume is  $6 \times 3 \times 15 \times 62.5 = 16,875$  pounds. Weight of timber, assumed at 10 per cent. of the water, 1,687 pounds. Total weight to be carried by the stringers,  $16,875 + 1,687 = 18,562$  pounds, half of which, or 9,281 pounds, goes to each stringer.

Since the stringers are to have a square cross-section,  $b = d$  and formula **222**, Art. **2189**, becomes  $W = \frac{4}{3} \frac{d^3}{l} S$ .

From the table in Art. **2193** we find the allowable unit stress  $S$  for white oak with a steady load to be 1,350 pounds.

Substituting in formula **222**, we have

$$9,281 = \frac{4}{3} \times \frac{d^3}{15 \times 12} \times 1,350,$$

from which  $d^3 = 928.1$  and  $d = 9.61$ , from which we see that the section of the stringers should be  $10'' \times 10''$ . Ans.

(1179) The total uniformly distributed load is  $1,500 \times 36 = 54,000$  pounds. We will assume the depth  $d$  of the tie-beam to be 14 inches; then, the allowable unit stress for spruce, from the table in Art. **2193**, being 1,250 pounds, we have, by substituting in formula **232**, Art. **2200**,

$$1,250 = \frac{1}{4} \times \frac{54,000 \times 36 \times 12}{b \times 14} \left( \frac{1}{2 \times 10 \times 12} + \frac{1}{3 \times 14} \right),$$

from which  $b = 9.32$  inches.

In order to provide for the holes for the queen-rods, we will make the tie-beam  $12'' \times 14''$ .

The total stress in the upper chord member, from formula **233**, Art. **2200**, is

$$S_c = \frac{1}{8} \times \frac{54,000 \times 36 \times 12}{10 \times 12} = 24,300 \text{ pounds;}$$

and, from formula **234**, the total stress in each of the struts is

$$S_s = 54,000 \sqrt{\frac{1}{9} + \frac{1}{64} \times \frac{36^2}{10^2}} = 30,240 \text{ pounds.}$$

The values obtained for  $S_c$  and  $S_s$  show that the struts

carry a heavier stress than the top chord member; we will, however, make them all the same size, computing the dimensions for the struts only.

The length of a strut is  $\sqrt{12^2 + 10^2} = 15.62$  ft. = 188 inches, nearly. Assuming a depth of 10 inches, a value of  $\frac{S}{f}$  of 1,250, and substituting in formula **79**, Art. **1171**, we have the breadth

$$b = \frac{30,240 \left( 1 + \frac{12 \times 188^2}{10^2 \times 3,000} \right)}{10 \times 1,250} = 5.84 \text{ inches.}$$

The struts and top chord member may, therefore, safely be made of 6"  $\times$  10" timbers.

Since the queen-rods are to be wrought iron, the safe unit stress may be taken as 12,000 pounds per square inch. Substituting in formula **235**, Art. **2200**, the net area is

$$A = \frac{1}{3} \times \frac{30,240}{12,000} = .84 \text{ sq. in.}$$

From a table of standard screw threads, we find that the area at the bottom of the thread of a  $1\frac{1}{4}$ -inch bolt is .893 sq. in.; consequently, a  $1\frac{1}{4}$ -inch queen-rod will be used.

(**1180**) One panel weight is  $1,800 \times 12 = 21,600$  pounds. By applying formula **236**, Art. **2202**, to the different ties, we have, remembering that the stress in the center tie is equal to 1 panel load,

Stress in  $c = 21,600$  pounds.

Stress in  $b = 1\frac{1}{2} \times 21,600 = 32,400$  pounds.

Stress in  $a = 2\frac{1}{2} \times 21,600 = 54,000$  pounds.

The length of each of the struts is  $L_s = \sqrt{8^2 + 12^2} = 14.42$  feet; therefore, the factor  $\frac{L_s}{L_t}$  in formula **237** becomes  $\frac{14.42}{8} = 1.8$ , very nearly, and the stress in the struts is for

Strut  $c'$ ,  $21,600 \times 1.8 = 38,880$  pounds.

Strut  $b'$ ,  $32,400 \times 1.8 = 58,320$  pounds.

Strut  $a'$ ,  $54,000 \times 1.8 = 97,200$  pounds.

The ratio of the length of the panel to the length of the tie is  $\frac{L_p}{L_t} = \frac{1}{8}^2 = 1\frac{1}{2}$ ; applying the known values to formula

**238**, we have for the different top chord members,

Stress in  $B' = 2 \times 21,600 (3 - 1) 1\frac{1}{2} = 129,600$  pounds.

Stress in  $A' = 21,600 (3 - \frac{1}{2}) 1\frac{1}{2} = 81,000$  pounds.

Applying formula **239**, we find that the stresses in the bottom chord members are as follows:

Stress in  $C = 21,600 (3 \times 2 + 3 - 2 - 2 - \frac{1}{2}) 1\frac{1}{2} = 145,800$  pounds.

Stress in  $B = 21,600 (3 + 3 - 1 - \frac{1}{2} - \frac{1}{2}) 1\frac{1}{2} = 129,600$  pounds.

Stress in  $A = 21,600 (3 - \frac{1}{2}) 1\frac{1}{2} = 81,000$  pounds.

(**1181**) (*a*) Since it went down 5 inches in six blows, its final set, or refusal, under the last blow was evidently less than an inch. Formula **240**, Art. **2205**, is therefore applicable, and we have

$$S = 3,000 \times 8 = 24,000 \text{ lb. Ans.}$$

(*b*) As the area of the head of the pile is 113 sq. in., and its safe resistance to crushing may be taken as 1,000 lb. per sq. in., its safe resistance to crushing is 113,000 lb., greatly in excess of the value found in the answer to (*a*) for the safe load against further penetration into the ground.

(**1182**) Overflow weirs and discharge gates. (Art. **2208**.)

(**1183**) In reduced freight, owing to less weight; to economy in handling and laying, for the same reason, and in the less number of joints. (Arts. **2210** to **2214**.)

(**1184**) Low pressures, and cheap supplies of the proper kind of lumber. (Art. **2215**.)

(**1185**) Yes; because loosened fragments of rock are always liable to fall and obstruct the passage of the water. To remove such fallen fragments, it is necessary to empty the tunnel, which may cause embarrassing interruptions of service. (Art. **2216**.)

(**1186**) By the slow saturation of the earth's crust through ages of rainfall. (Art. **2217**.)

(1187) A great reservoir, in which the rainfall of many centuries has been stored away. (Art. 2217.)

(1188) Deep and shallow. (Arts. 2218 and 2219.)

(1189) Into flowing and non-flowing wells. The former only being properly called artesian. (Art. 2219.)

(1190) See Art. 2220.

(1191) One that develops at least one indicated horsepower, by the combustion of two pounds of good coal per hour. (Art. 2227.)

(1192) When large volumes of water are to be pumped with regularity in localities where fuel is dear, and where there are facilities for running and maintaining the costly and complicated high-duty pumping engine. (Art. 2227.)

(1193) Irrigation by sprinkling consists in moistening the ground by throwing water upon it in the form of spray. Its advantages are: that a thorough and gradual saturation may be administered to all parts of the field, with no special preparation of the ground in the way of leveling and grading, and the watering being at all times under perfect control. The use of this method is naturally inconvenient and expensive when applied to very large tracts requiring large volumes of water, owing to the necessity of pipes, hydrants, pumps, hose, etc., for its application. (Art. 2232.)

(1194) The object of this system of irrigation is to spread a thin sheet of water as uniformly as possible over the land. To accomplish this some preliminary work in the way of leveling and grading is almost invariably necessary. This being accomplished, water is led by a ditch along the upper level of the field to be treated, and by means of temporary obstacles placed in the ditch, it is caused to slowly overflow and spread over the land below it. Or, breaks or openings are made at certain intervals in the ditch, through which the water runs out and spreads over the lower portions of the field. The course of the water must be carefully watched and directed while it is being laid on. (Art. 2233.)

(1195) (*a*) Land lying on a gentle and regular slope.  
 (*b*) It is the simplest and cheapest method of irrigation, but is wasteful of water, and very irregular in its distribution. (Art. 2233.)

(1196) By running a number of parallel ditches, one below the other, across the slope of the ground, at short distances apart, dividing the hillside into zones or belts. These belts are successively watered, commencing with the upper one, the unabsorbed water passing to the next ditch below, and so on. (Art. 2233.)

(1197) In the check system, the auxiliary ditches just described are replaced by ridges, or low dams, rudely thrown up. Their object is to submerge the land lying between the ridges or checks, and to allow the water to remain upon it until it becomes sufficiently saturated. It is then drawn off, and allowed to flood the next zone below. The checker-board system is a modification of the above, and consists in crossing the checks just described by others, running up and down hill, dividing the land into a series of compartments, which are flooded successively. Both of these methods—particularly the latter—are adapted to very level land. (Arts. 2234 and 2235.)

(1198) (*a*) In the furrow system the water is led between the rows or hills in which the crops are planted, and the moistening of the soil takes place by lateral absorption.  
 (*b*) Orchards, and all crops sown in hills or rows. (Art. 2236.)

(1199) A careful preparation of the land, good drainage, and cultivation. (Art. 2158.)

(1200) Economy of water, and combining irrigation with drainage, in certain cases. (Art. 2237.)

(1201) The cubic foot and the second. (Art. 2240.)

(1202)  $1 \div 38.4 = 0.026$  cu. ft. per second. (Art. 2240.)



(1203) Securing a proper supply of water, transporting it to where it is to be used, and distributing it to consumers in measured volumes. (Art. **2242**.)

(1204) \$10.55 and \$84.25. (See Table, Art. **2244**.)

(1205) \$15.84; \$22.27; \$19.00. (See Table, Art. **2244**.)

(1206) The sewage of a town is generally discharged into some neighboring stream or watercourse. This leads to the greater or less pollution of the stream, which may be the source of supply to some other community, or a feeder thereto. Consequently, unless the town sewage can be emptied into the sea, or a large bay, or powerful tidal river, it becomes necessary, in the interest of public health, to purify the sewage before allowing it to empty into any watercourse, the contamination of which would be likely to be injurious to other communities. (Arts. **2253** and **2254**.)

(1207) Depriving it of the injurious ingredients which it contains, in suspension or in solution, so that the effluent may be wholly or partly innoxious, to the extent of allowing it to be emptied into a source of public water supply without seriously polluting it. (Art. **2254**.)

(1208) Chemical precipitation, intermittent filtration, and broad irrigation. (Arts. **2254** to **2257**.)

(1209) In the liquid form. (Art. **2253**.)

(1210) By means of sewage irrigation areas, supplemented by filter beds capable themselves of producing certain crops. (Arts. **2257** and **2258**.)

(1211) The water supply of the town. (Art. **2259**.)

(1212) As much as 40 to 50 feet. (Art. **2260**.)

(1213) Alfalfa, Indian corn sown for forage, garden crops, etc. (Art. **2261**.)

(1214) Yes; trouble may be apprehended when the mean winter temperature falls for any considerable time much below 20° to 25° F. (Art. 2262.)

(1215) The ridge-and-furrow system is merely an improved form of the flooding system, as adapted to specially prepared ground. A ditch is run along the top of the artificially made ridges, and allowed to overflow along the adjoining slopes. The pipe-and-hydrant system consists in running pipes supplied with hydrants somewhat as would be done for sprinkling irrigation. The catch-work method is virtually the same as the "check" system of irrigation. It is adapted to steeper ground than the ridge-and-furrow method, and is generally preferred when the ground has a sufficient slope to permit of its use. The absorption-ditch system has its parallel in the furrow system of irrigation. It is particularly well adapted to the application of sewage to intermittent filter beds, when it is desired to raise crops upon them. (Arts. 2264 to 2268.)

(1216) Plain water irrigation can and should be practised year after year upon the same piece of land. In sewage irrigation, it is frequently found advantageous to divide the land into small plots, applying the sewage in rotation to each, rather than treating the entire area as a whole. (Art. 2269.)

(1217) That the water of all natural streams belongs to the public until appropriated to beneficial use, and then to the prior appropriator. (Art. 2271.)

# HEAT.

(QUESTIONS 554-613.)

(554) 9 hr. 25 min. = 565 min.

$55 \div 2 = 27.5$  min. = time it would take to heat 1 lb. of the substance to this temperature under the same conditions.  
 $27.5 \div 565 = .04867$  = specific heat of the substance. Ans.

(555) Increase in diameter =  $4.001 - 3.9985 = .0025''$ .  
 $C_1 = .00000599$ , from Table 19. Hence, using formula  
**67**,  $t = \frac{1}{L C_1} = \frac{.0025}{3.9985 \times .00000599} = 104.4^\circ$ , nearly. Then,  
 $104.4 + 80 = 184.4^\circ$ , nearly. Ans.

(556) (a) Substituting in formula **72**  $W = 360$ ,  $t_1 - t = 104.4$ , and  $s = .1165$ ;  $n = W (t_1 - t) s = 360 \times 104.4 \times .1165 = 4,378.536$  B. T. U.

Since 12% of the total heat is lost by radiation, the above number of B. T. U. must be the number remaining after subtracting the heat units lost by radiation from the total number; or it is  $100 - 12 = 88\%$  of the total number. Hence, dividing by .88 we obtain  $4,378.536 \div .88 = 4,975.6$  B. T. U., total heat required. Ans.

(b)  $4,975.6 \times 778 = 3,871,017$  ft.-lb. Ans.

(557) (a)  $80^2 \times .7854 = 5,026.56$  sq. in. = area of piston.

$p v = p_1 v_1$ . At the beginning of the stroke  $p = 14.7$ , and the volume may be represented by the length of the cylinder, 80 in.; at the point of discharge  $p_1$  is 120, therefore,  $80 \times 14.7 = 120 \times v$ , or  $v = 9.8$  in., the portion of the stroke uncompleted at discharge.

$\frac{5,026.56 \times 9.8}{1,728} = 28.507$  cu. ft., volume of air discharged.

Ans.

(b) By formula **80**,  $L = 331.5744 p V \log \frac{p_1}{p} = 331.5744 \times 120 \times 28.507 \log \frac{120}{14.7} = 331.5744 \times 120 \times 28.507 \times .91186 = 1,034,289 \text{ ft.-lb.}$  Ans.

(558) (a) Volume of cylinder = area of piston  $\times$  length of stroke  $= \frac{5,026.56}{144} \times \frac{80}{12} = 232.71 \text{ cu. ft., nearly.}$

From formula **81**,  $p_1 v_1^{1.41} = p_2 v_2^{1.41}$ , or  $v_2 = \sqrt[1.41]{\frac{p_1 v_1^{1.41}}{p_2}}$ .

Substituting for  $p_1$  and  $v_1$  their values at the beginning of the stroke, and for  $p_2$  its value at discharge, we have

$$v_2 = \sqrt[1.41]{\frac{14.7 \times 232.71^{1.41}}{120}};$$

$$\log v_2 = \frac{\log 14.7 + 1.41 \log 232.71 - \log 120}{1.41}, \text{ or}$$

$$\log v_2 = \frac{1.16732 + 1.41 \times 2.36682 - 2.07918}{1.41} = 1.72011.$$

$v_2 = 52.494 \text{ cu. ft., the volume discharged.}$  Ans.

(b) To find the work, use formula **84**,

$$L = 351.36 p V \left[ 1 - \left( \frac{V}{V_1} \right)^{.41} \right] =$$

$$351.36 \times 14.7 \times 232.71 \times \left[ 1 - \left( \frac{232.71}{52.494} \right)^{.41} \right].$$

$\text{Log} \left( \frac{232.71}{52.494} \right)^{.41} = .41 (\log 232.71 - \log 52.494) = .41 (2.36682 - 1.72011) = .26515.$  Therefore,  $\left( \frac{232.71}{52.494} \right)^{.41} = 1.8414.$

$1 - 1.8414 = -.8414$ , the minus sign indicating that the work done by the air is negative; that is, that work is done upon the air instead of by it, or that the air is compressed.

$$L = 351.36 \times 14.7 \times 232.71 \times .8414 = 1,011,317 \text{ ft.-lb.}$$

Ans.

(559) See Arts. **1090** and **1135**.

(560) Using formula 65,

$$(a) \quad t_f = \frac{2}{5} \times 2,917 + 32 = 5,282.6^\circ \text{ F.} \quad \text{Ans.}$$

$$(b) \quad t_f = \frac{2}{5} \times 637 + 32 = 1,178.6^\circ \text{ F.} \quad \text{Ans.}$$

$$(c) \quad t_f = \frac{2}{5} \times (-260) + 32 = -436^\circ \text{ F.} \quad \text{Ans.}$$

(561) See Table 21, Art. 1134, and Table 22, Art. 1141.

$-50 - (-37.8) \times 12 \times .0333 = 4.875 =$  units of heat necessary to raise the temperature to the fusion point.  
 $5.09 \times 12 = 61.08$  B. T. U. required to melt the mercury.  
 $[662 - (-37.8)] \times .0333 \times 12 = 279.64$  B. T. U. required to raise the temperature to the point of vaporization.  
 $157 \times 12 = 1,884$  B. T. U. required for vaporizing it.  
 $4,875 + 61.08 + 279.64 + 1,884 = 2,229.595$  B. T. U. Ans.

(562) Using formula 71,  $pV = WR T$ , or

$$W = \frac{pv}{RT} = \frac{18 \times 100}{5.34946 \times 540} = .6231 \text{ lb.} \quad \text{Ans.}$$

(563) See Tables 21 and 22 for specific heat and temperature of fusion of copper. 7 lb. 5 oz. = 7.3125 lb.  
 $2,100^\circ - 78^\circ = 2,022^\circ$ .  $2,022 \times 7.3125 \times .0951 = 1,406.13$  B. T. U. Ans.

(564) By formula 73,  $t = \frac{W_1 s_1 t_1 + W_2 s_2 t_2 + W_3 s_3 t_3}{W_1 s_1 + W_2 s_2 + W_3 s_3} =$   
 $\frac{2.25 \times .0314 \times 40 + 4 \times 65 + 1.75 \times .1298 \times 62}{2.25 \times .0314 + 4 + 1.75 \times .1298} = 64.43^\circ$ . Ans.

(565) Use formulas 69, 67, and 68. (a)  $v = VC_s t = 4 \times 4 \times 20 \times 1,200 \times .00002058 = 7.903$  cu. in. Ans.

(b)  $l = LC_1 t = 20 \times 1,200 \times .00000686 = .16464$  in. Ans.

(c)  $a = AC_2 t = 4 \times 4 \times 1,200 \times .00001372 = .2634$  sq. in. Ans.

(566) Using formula 71,

$$pV = WR T, \text{ or } T = \frac{pV}{WR} = \frac{73 \times 61}{10 \times .38143} = 1,167.45^\circ.$$

$$1,167.45^\circ - 460^\circ = 707.45^\circ. \quad \text{Ans.}$$

(567) See Art. 1124.

(568) By formula 73,  $t = \frac{W_1 s_1 t_1 + W_2 s_2 t_2 + W_3 s_3 t_3}{W_1 s_1 + W_2 s_2 + W_3 s_3}$ , or

$$t_1 = \frac{(W_1 s_1 + W_2 s_2 + W_3 s_3) t - W_2 s_2 t_2 - W_3 s_3 t_3}{W_1 s_1} =$$

$$\frac{(1 \times .1298 + 3.25 \times 1 + 1.5 \times .0951) 128 - 3.25 \times 85 - 1.5 \times .0951 \times 85}{1 \times .1298} =$$

1,252°. Ans.

(569) Draw the lines  $OX$  and  $OY$  (Fig. 46) perpendicular to each other. On  $OX$  take any convenient distance, say  $\frac{1}{2}$  inch, to represent one unit of volume (1 cu. ft.), and on  $OY$  take a distance of say 3 inches to represent the required pressure of 84 pounds. Our scale of pressure is,

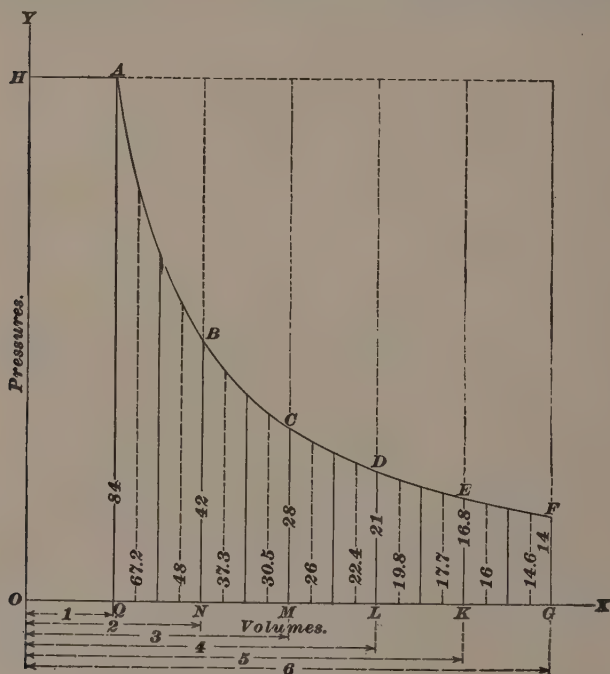


FIG. 46.

then, 28 pounds to the inch. The ordinates are now erected as shown in Art. 1156. Thus, at  $A$  the volume is 1, and

the pressure 84 pounds; hence,  $p v = 84$ . But  $p v = p_1 v_1 = p_2 v_2$ , etc., = 84; hence,  $p_1 = \frac{84}{v_1}$ ,  $p_2 = \frac{84}{v_2}$ , etc. When  $v = 1$ ,  $p = \frac{84}{1} = 84 = Q A$ .

$$\text{When } v = 2, p = \frac{84}{2} = 42 = N B.$$

$$\text{When } v = 3, p = \frac{84}{3} = 28 = M C.$$

$$\text{When } v = 4, p = \frac{84}{4} = 21 = L D.$$

$$\text{When } v = 5, p = \frac{84}{5} = 16.8 = K E.$$

$$\text{When } v = 6, p = \frac{84}{6} = 14 = G F.$$

A curve through  $A, B, C, D, E$ , and  $F$  will be the one required.

(570) Divide the space  $Q G$  into 10 equal parts, as shown in the figure, and draw the ordinate at the middle of each space. The average ordinate will be found to be 29.95 lb. The volume represented by the length  $Q G$  is 5 cu. ft. Hence, the work is  $29.95 \times 5 \times 144 = 21,564$  foot-pounds. Ans.

Calculating the work by formula 79,

$$L = 331.5744 p V \log \frac{V_1}{V};$$

$$L = 331.5744 \times 84 \times 1 \times \log \frac{6}{1} = 21,673 \text{ ft.-lb. Ans.}$$

(571) (a)  $460 + 96 = 556^\circ \text{ F.}$  (b)  $273\frac{1}{2} + 32 = 305\frac{1}{2}^\circ \text{ C.}$   
(c)  $273\frac{1}{2} + 180 = 453\frac{1}{2}^\circ \text{ C.}$  (d)  $460 + 650 = 1,110^\circ \text{ F.}$  (e)  $273\frac{1}{2} - 40 = 233\frac{1}{2}^\circ \text{ C.}$

(572)  $32^\circ - 20^\circ = 12^\circ$ .  $12 \times 7 \times .504 = 42.336 \text{ B. T. U.}$  required to heat the ice to  $32^\circ$ .  $142.65 \times 7 = 998.55 \text{ B. T. U.}$  required to melt the ice.  $212^\circ - 32^\circ = 180^\circ$ .  $180 \times 7 \times 1 = 1,260 \text{ B. T. U.}$  required to heat the water to  $212^\circ$ .  $966.6 \times 7 = 6,766.2 \text{ B. T. U.}$  required to change 7 lb. of water at  $212^\circ$  into steam at  $212^\circ$ .  $42.336 + 998.55 + 1,260 + 6,766.2 = 9,067.086 \text{ B. T. U.}$

$$\frac{9,067.086 \times 778}{43 \times 33,000} = 4.971 \text{ horsepower. Ans.}$$

(573) Using formula 84, and substituting the values of  $p$  and  $V$  at beginning of compression, we have

$$L = 351.36 p V \left[ 1 - \left( \frac{V}{V_1} \right)^{.41} \right] =$$

$$351.36 \times 14.7 \times 1 \left[ 1 - \left( \frac{1}{.25} \right)^{.41} \right].$$

$$\text{Log} \left( \frac{1}{.25} \right)^{.41} = \log 4^{.41} = .41 \log 4 = .41 \times .60206 = .24684.$$

The number whose logarithm is .24684 is 1.7654.

Therefore,  $\left( \frac{1}{.25} \right)^{.41} = 1.7654$ .  $1 - \left( \frac{1}{.25} \right)^{.41} = 1 - 1.7654 = -.7654$ , the minus sign indicating that the air is compressed. Hence,  $L = 351.36 \times 14.7 \times .7654 = 3,953.28$  ft.-lb. Ans.

(574) On account of the great irregularity in outline of this figure, a division into ten parts will not give a sufficiently close approximation to the mean ordinate; hence, it is divided into 20 equal parts, as shown by the full lines.

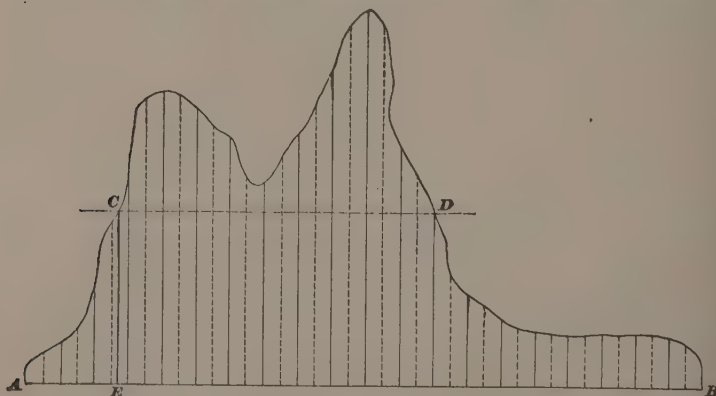


FIG. 47.

(See Fig. 47.) The dotted lines, situated midway between the full lines, represent the ordinates which are to be measured. The sum of all the dotted lines, divided by the number of divisions, gives .9365" for the mean ordinate. Draw



the line  $CD$  parallel to  $AB$  at a distance from  $AB$  equal to  $.9365''$ , and where it cuts the curve will be the points from which to draw the mean ordinate, as  $CE$ .

(575) Prolong  $AB$  in both directions as shown in Fig. 48. Draw the tangents  $hi$ ,  $fA$ ,  $cd$ , and  $cb$ , perpendicular to  $AB$ . Since the outline  $fAg$  is very nearly triangular, and is quite small compared with the rest of the figure, consider it a triangle, and draw  $mn$  half way

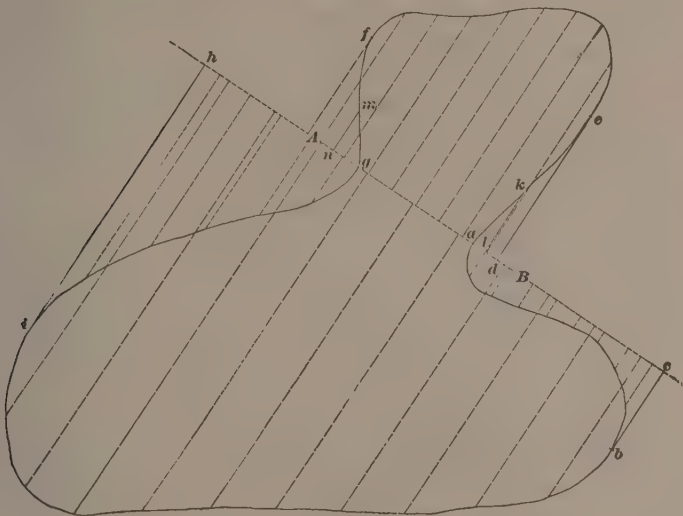


FIG. 48.

between  $A$  and  $g$ . Consider  $mn$  as the mean ordinate. Then,  $A g \times m n = .34 \times .28 = .0952$  sq. in. In a similar manner, area of  $a d c = .17 \times .4 = .068$  sq. in. Dividing  $A f c d$  into 8 equal parts, and drawing the ordinates at the middle points of these divisions (for convenience the full lines, similar to those in the last figure, have been omitted, and the ordinates at the middle points only have been drawn), the mean ordinate is found to be  $1.228''$ . The length  $A d = 1.31''$ ; hence, area of  $A f c d = 1.31 \times 1.228 = 1.6087$  sq. in. Dividing  $a c b$  into 8 equal parts, the mean

ordinate is found to be .154; the length  $ac$  is 1.34; hence, area  $acb = 1.34 \times .154 = .2064$  sq. in. Dividing  $hgi$  into 5 equal parts, the mean ordinate is found to be .82"; the length  $hg$  is 1.07"; hence, area  $hgi = 1.07 \times .82 = .8774$  sq. in. Dividing  $hibc$  into 10 equal parts, the mean ordinate is found to be 1.925"; its length  $hc = 3.21$ "; hence, area  $hibc = 3.21 \times 1.925 = 6.179$  sq. in.

$$1.6087 + 6.179 = 7.7877 \text{ sq in.} = \text{area } hibcdefAh.$$

$$.0952 + .068 + .2064 + .8774 = 1.247 \text{ sq. in.}$$

$$7.7877 - 1.247 = 6.5407 \text{ sq. in.} = \text{required area } gibacfg.$$

Ans.

(576) Using formula 73,  $t = \frac{W_1 s_1 t_1 + W_2 s_2 t_2 + W_3 s_3 t_3}{W_1 s_1 + W_2 s_2 + W_3 s_3}.$

For water,  $s_1 = 1$ ; therefore,  $W_1 t + (W_2 s_2 + W_3 s_3) t = W_1 t_1 + W_2 s_2 t_2 + W_3 s_3 t_3$ , and

$$W_1 = \frac{W_2 s_2 t_2 + W_3 s_3 t_3 - t (W_2 s_2 + W_3 s_3)}{t - t_1}.$$

Substituting the given values for  $W$  and  $t$  and the values of  $s_2, s_3$ , etc., from Table 21, we have

$$W_1 = \frac{4 \times .426 \times 80 + .5 \times .0939 \times 73 - 75.61(4 \times .426 + .5 \times .0939)}{75.61 - 73}$$

$$= \frac{7.35802}{2.61} = 2.819 \text{ lb.} \quad \text{Ans.}$$

(577) See Arts. 1138, 1139, 1131, 1132, and 1152.

(578)  $K = \frac{W v^2}{2g} = \frac{120 \times 1,200^2}{2 \times 32.16} = \text{kinetic energy in foot-pounds.}$

(See Art. 957.)  $\frac{120 \times 1,200^2}{2 \times 32.16} \times .15 = \text{kinetic energy expended in heat.}$  Now, dividing by 778 to reduce the foot-pounds to B.T.U.,  $\frac{120 \times 1200^2 \times .15}{2 \times 32.16 \times 778} = 517.975 \text{ B.T.U.} \quad \text{Ans.}$

(579) See Art. 1126.

(580) Using formula 73,  $t = \frac{W_1 s_1 t_1 + W_2 s_2 t_2 + W_3 s_3 t_3}{W_1 s_1 + W_2 s_2 + W_3 s_3}.$

(Since  $s_2$ , the specific heat of water, is 1, it may be left out )

Transposing,

$$s_1 = \frac{W_2(t_2 - t) + W_3 s_3(t_3 - t)}{W_1(t - t_1)} = \frac{1.875(91 - 86) + 1.25 \times .0562 \times (91 - 86)}{5(86 - 40)} = .0423. \text{ Ans.}$$

(See example, Art. 1137.)

$$(581) \quad T_1 = 460^\circ + 450^\circ = 910^\circ; \quad T_2 = 460^\circ + 70^\circ = 530^\circ.$$

$$\text{Efficiency} = \frac{T_1 - T_2}{T_1} = \frac{910 - 530}{910} = 41.76\%. \text{ Ans.}$$

$$(582) \quad \text{Use formula 71, } pV = WR T. \quad T = 460^\circ + 200 = 660^\circ; \text{ and } R, \text{ from Table 20, is } 5.34946; \text{ therefore, } W = \frac{pV}{RT} = \frac{20 \times 700}{5.34946 \times 660} = 3.9653 \text{ lb. Ans.}$$

(583) (See Arts. 1091 to 1098.)

$$(a) \quad C : R = 100 : 80, \text{ or } C = \frac{100}{80} R = \frac{5}{4} R.$$

$$\text{Hence, } 44 \times \frac{5}{4} = 55^\circ \text{C. Ans.}$$

$$(b) \quad F : R = 180 : 80, \text{ or } F = \frac{180}{80} R = \frac{9}{4} R.$$

$$\text{Hence, } 44 \times \frac{9}{4} + 32 = 131^\circ \text{F. Ans.}$$

(584) By formula 81,  $p_1 v_1^{1.41} = p_2 v_2^{1.41}$ . The volume of 1 lb. of air at atmospheric pressure, and having a temperature of  $60^\circ$ , is  $\frac{1}{.076296} = 13.107$  cu. ft. (See question 510.)

Substituting in the above formula,  $14.7 \times 13.107^{1.41} = 235 \times v_2^{1.41}$ , or

$$v_2 = \sqrt[1.41]{\frac{14.7 \times 13.107^{1.41}}{235}} = 1.8356 \text{ cu. ft. Ans.}$$

From formula 71, remembering that  $W = 1$ , we have  $pV = RT$ , or  $T = \frac{pV}{R} = \frac{235 \times 1.8356}{.37052} = 1,164.2^\circ$ .  $1,164.2^\circ - 460^\circ = 704.2^\circ$ . Ans.

(585) (See Arts. 1107, 1054, and 1099.)

(586) (a) Cubical contents of cylinder  $= (10^3 - 9\frac{1}{4}^3) \times .7854 \times 72 = 816.48$  cu. in.  $= \frac{816.48}{1,728}$  cu. ft. Specific gravity of copper is 8.79. Then, the weight of the cylinder is  $\frac{816.48}{1,728} \times 62.5 \times 8.79 = 259.58$  lb. Specific heat of copper, from Table 21, is .0951. Substituting the values of  $n$ ,  $W$ , and  $s$ , in formula 72,  $n = IV(t_1 - t)s$ , we have  $7,000 = 259.58(t_1 - t) \times .0951$ , or  $t_1 - t = \frac{7,000}{259.58 \times .0951} = 283.56^\circ =$  increase of temperature.

By formula 67,  $l = L C_1 t = 72 \times .00000955 \times 283.56 = .195$  in. Ans.

(b) By formula 69,  $v = V C_2 t = 816.48 \times .00002864 \times 283.56 = 6.63$  cu. in. Ans.

(c) By formula 67,  $l = L C_1 t = 10 \times .00000955 \times 283.56 = .027$  in. Ans.

(587) From Table 19, the coefficient of expansion for gases is .00203252. Substituting in formula 70,

$$V_2 = \left[ \frac{1 + C_a(t_2 - 32)}{1 + C_a(t_1 - 32)} \right] V_1 = \left[ \frac{1 + .00203252(390 - 32)}{1 + .00203252(65 - 32)} \right] \times 12 = 19.428 \text{ cu. ft. } 19.428 - 12 = 7.428 \text{ cu. ft. Ans.}$$

The same answer may be obtained by using formula 58.

(588) Foot-pounds per minute  $= 75 \times 2 \times 20 \times 2 \times .18$ .

Foot-pounds per hour  $= 75 \times 2 \times 2 \times 20 \times .18 \times 60$ .

$$\text{Heat units per hour} = \frac{75 \times 2 \times 2 \times 20 \times .18 \times 60}{778} = 83.29$$

B. T. U. Ans.

(589) (a) Using formula 87,  $T_1 = T \left( \frac{V}{V_1} \right)^{.41} = 610 \times \left( \frac{1}{4.5} \right)^{.41} = -130.76^\circ$ . Ans.

(b) Substituting in formula 71, the initial values of  $W$ ,  $R$ ,  $T$ , and  $V$ , we obtain  $p = \frac{WR T}{V} = \frac{.5 \times .37052 \times 610}{.9} = 125.565$  lb. per sq. in., the initial pressure. Ans.

(c) Using formula 86,

$$p_1 = p \left( \frac{T_1}{T} \right)^{.50678} = 125.565 \times \left( \frac{329.24}{610} \right)^{.50678} = 15.06 \text{ lb. per sq. in.}$$

Ans.

(590)  $12^3 \times .5236 = 904.78 \text{ cu. in.} = \text{volume of sphere.}$

Sp. Gr. of zinc = 6.86; therefore,  $\frac{904.78}{1,728} \times 62.5 \times 6.86 = 224.5 \text{ lb.} = \text{weight of sphere.}$  (See example 586.) Using formula 73,  $t = \frac{W_1 s_1 t_1 + W_2 s_2 t_2}{W_1 s_1 + W_2 s_2} = \frac{8 \times 212 + 224.5 \times .0956 \times 70}{8 + 224.5 \times .0956} = 108.49^\circ.$   $108.49^\circ - 70^\circ = 38.49^\circ = \text{increase in temperature of the zinc sphere after dipping in the boiling water.}$

Using formula 69,  $v = V C_s t = 904.78 \times .00004903 \times 38.49 = 1.71 \text{ cu. in., nearly.}$  Ans.

(591) By formula 67,  $l = L C_1 t.$   $C_1 = .00000599;$   $L = 900 \times 12;$   $t = 90^\circ - 28^\circ;$  therefore,  $l = 900 \times 12 \times .00000599 \times (90 - 28) = 4.01 \text{ in.}$  Ans.

(592) According to formula 72,  $n = W(t_1 - t)s,$  or  $s = \frac{n}{W(t_1 - t)} = \frac{n}{W} = \frac{5}{26} = .1923.$  Ans.

(593) See Art. 1161.

(594) (a) Temperature of vaporization of sulphur, from Table 22, is  $228.3^\circ.$

Specific heat of sulphur, from Table 21, is .2026.

Latent heat of fusion of sulphur, from Table 22, is 13.26.

$228.3 - 40 = 188.3.$   $13 \times .2026 \times 188.3 = 495.94454$

B. T. U. to raise sulphur to melting point.  $13.26 \times 13 = 172.38$  B. T. U. to melt the sulphur.  $(495.94454 + 172.38) \times 778 \times 519,956.5 \text{ ft.-lb., total work required to perform both of the above operations.}$  Ans.

(b)  $\frac{519,956.5}{10 \times 33,000} = 1.5756 \text{ horsepower.}$  Ans.

(595)  $124 \times 3 = 372$  B. T. U., heat given up by the turpentine in changing from gas to liquid.  $75 \times 4 = 300$  B. T. U., heat contained in the water.  $300 + 372 = 672$

B. T. U., heat contained in the mixture at the instant the turpentine has become liquid.  $672 \div 4 = 168^\circ =$  temperature of water at the instant that the turpentine has become a liquid.

Applying formula 73,  $t = \frac{W_1 s_1 t_1 + W_2 s_2 t_2}{W_1 s_1 + W_2 s_2} =$   
 $\frac{.3 \times .426 \times 313 + 168 \times 4}{3 \times .426 + 4} = 203.11^\circ, \text{ final temperature. Ans.}$

(596) Specific heat of melted lead, from Table 21, = .0402.

Specific heat of solid lead, from Table 21, = .0314.

Temperature of fusion of lead, from Table 22, =  $626^\circ$ .

Latent heat of fusion of lead, from Table 22, = 9.67.

$$626^\circ - 46^\circ = 580^\circ. \quad 800^\circ - 626^\circ = 174^\circ.$$

$25 \times .0314 \times 580 = 455.3$  B. T. U., heat required to raise the lead to melting point.  $9.67 \times 25 = 241.75$  B. T. U., heat required to melt the lead.  $25 \times .0402 \times 174 = 174.87$  B. T. U., heat required to raise the temperature of the melted lead from fusion point to  $800^\circ$ .  $455.3 + 241.75 + 174.87 = 871.92$  B. T. U., total heat required.  $871.92 \times 778 = 678,353.76$  ft.-lb. Ans.

(597)  $32^\circ - 10^\circ = 22^\circ$ .  $22 \times 10 \times .504 = 110.88$  B. T. U., heat required to raise ice from  $10^\circ$  to  $32^\circ$ . Latent heat of fusion of ice, from Table 22, is 142.65; then  $142.65 \times 10 = 1,426.5$  B. T. U., heat units to melt the ice.  $1,426.5 + 110.88 = 1,537.38$  B. T. U., total heat units to be taken from the mixture to melt the ice. Hence, applying formula 73,

$$t = \frac{W_1 s_1 t_1 + W_2 s_2 t_2 + W_3 t_3 + W_4 t_4 + W_5 s_5 t_5 - 1,537.38}{W_1 s_1 + W_2 s_2 + W_3 + W_4 + W_5 s_5} =$$

$$\frac{11.5 \times .1208 \times 180 + 42 \times .0989 \times 240 + 10 \times 32 + 50 \times 120 + 20 \times .0314 \times 80 - 1,537.38}{11.5 \times .1208 + 42 \times .0989 + 10 + 50 + 20 \times .0314}$$

=  $91.55^\circ$ . Ans.

(598) (a)  $p_1 v_1^{1.41} = p_2 v_2^{1.41}$ , or  $p_2 = \frac{140 \times 3^{1.41}}{16^{1.41}} = 13.215$

$$\text{Area} = \frac{p_1 v_1 - p_2 v_2}{.41} = \frac{140 \times 3 - 13.215 \times 16}{.41} = 508.69.$$

$$508.69 \div 20 = 25.434 \text{ sq. in. Ans.}$$

(b)  $25.434 \div 13 = 1.9565$ . Ans.

(c)  $1.9565 \times 20 = 39.13$  lb. per sq. in. Ans.

(599) Use formula 66,  $t_c = (t_f - 32) \frac{5}{9}$ .

(a)  $t_o = (-10 - 32) \times \frac{5}{9} = -23\frac{1}{3}^\circ \text{C}$ . Ans.

(b)  $t_o = (25 - 32) \times \frac{5}{9} = -3\frac{2}{3}^\circ \text{C}$ . Ans.

(c)  $t_o = (2,200 - 32) \times \frac{5}{9} = 1,204\frac{1}{3}^\circ \text{C}$ . Ans.

(600) This must be answered by the student.

(601) Using formula 80,  $L = 331.5744 p v \log \frac{p_1}{p} =$

$331.5744 \times 15 \times 10 \times \log \frac{85}{15} = 37,467.74$  ft.-lb. Ans.

(602) 520 H. P. =  $520 \times 33,000$  ft.-lb. per minute =  
 $520 \times 33,000 \times 60$  ft.-lb. per hour =

$\frac{520 \times 33,000 \times 60}{778}$  B. T. U. = 1,323,393.31 B. T. U. Ans.

(603) Let  $l$  = the required latent heat;

$W_1$  = given weight of zinc;

$W_2$  = given weight of water;

$s_1$  = specific heat of zinc;

$s_2$  = specific heat of water (= 1);

$t_1$  = temperature of melting zinc;

$t_2$  = temperature of water.

Then, the total heat of the mixture is  $W_1 s_1 t_1 + W_2 s_2 t_2 + W_1 l$ , and from formula 73, the temperature

$$t = \frac{W_1 s_1 t_1 + W_2 s_2 t_2 + W_1 l}{W_1 s_1 + W_2}, \text{ or}$$

$$l = \frac{t(W_1 s_1 + W_2) - W_1 s_1 t_1 - W_2 s_2 t_2}{W_1}$$

$$\frac{102\frac{1}{3}(4 \times .0956 + 10) - 4 \times .0956 \times 680 - 10 \times 60}{4} = 50.61.$$

Ans.

(604) See Arts. 1117 and 1120.

(605) (a) and (b) See Art. 1118.

(c) A non-conductor is one which will not conduct heat. There really is no such substance, but some substances are such bad conductors that they are termed non-conductors.

(606) When answering this question, consult Art. **1123**.

(607) In Art. **1130** it is stated that 1 calorie = 3.96 B. T. U. Hence, (a)  $798 \text{ B. T. U.} = 798 \div 3.96 = 201.515$  calories. Ans.

(b)  $40 \times 3.96 = 158.4 \text{ B. T. U.}$  Ans.

(608) (a) First calculate the weight by formula **71**.

$$W = \frac{\rho V}{R T} = \frac{18 \times 7.68}{.33552 \times 500} = .824 \text{ lb., nearly.}$$

Units of heat required =  $s_v W (T_1 - T) = s_v W (t_1 - t)$   
 $= .15507 \times .824 \times (416 - 40) = 48.0444 \text{ B. T. U.}$

Therefore,  $48.0444 \times 778 = 37,379 \text{ ft.-lb., nearly.}$  Ans.

(b)  $.21751 \times .824 (416 - 40) \times 778 = 52,429 \text{ ft.-lb., nearly.}$   
 Ans.

(609) See Arts. **1144** to **1147**.

(610) See Arts. **1155** and **1164**.

(611) Using formula **87**,

$T_1 = T \left( \frac{V}{V_1} \right)^{.41} = 528 \left( \frac{3.72}{1.2} \right)^{.41} = 839.64^\circ = 380^\circ$ , nearly, above  
 $0^\circ \text{ F.}$  Ans.

(612) (See Arts. **1149** and **1177**.)

(613) Use formula **81**,  $\rho v^{1.41} = \rho_1 v_1^{1.41}$ .

$14.7 \times 48^{1.41} = \rho_1 \times (48 - 38)^{1.41}$ , or

$$\rho_1 = 14.7 \left( \frac{48}{10} \right)^{1.41} = 134.24 \text{ lb. per sq. in.}$$
 Ans.

Now, using formula **86**,

$T_1 = 500 \left( \frac{134.24}{14.7} \right)^{.20078} = 951^\circ$ , nearly,  $= 491^\circ$  above  $0^\circ \text{ F.}$   
 Ans.



# STEAM AND STEAM ENGINES.

(QUESTIONS 614-688.)

(614) See Arts. **1191** and **1192**.

(615) See Arts. **1189** to **1195**.

(616) See Arts. **1198** to **1201**.

(617)  $\text{Log } p = 6.1007 - \frac{2,719.78}{T} - \frac{400,215}{T^2} = 6.1007 -$   
 $\frac{2,719.78}{290 + 460} - \frac{400,215}{(290 + 460)^2} = 1.76284.$  Hence,  $p = 57.92$  lb.  
 per sq. in. Ans.

(618) Using formula **91**,

$$H = 1,081.94 + 305 \, t = 1,081.94 + .305 \times 318 = 1,178.93$$

B. T. U. Ans.

(619) See Arts. **1217** and **1218**.

(620) Using formula **92**,

$$p v^{\frac{1}{16}} = 475, \text{ or } v^{\frac{1}{16}} = \frac{475}{p} = \frac{475}{81}.$$

Hence,

$$\frac{17}{16} \log v = \log 475 - \log 81 = 2.67669 - 1.90849 = .76820$$

$$\log v = .76820 \times \frac{16}{17} = .72301.$$

$v = 5.2846$  cu. ft. = volume of one pound.

$$5.2846 \times 6 = 31.7076 \text{ cu. ft. Ans.}$$

(621) Using formula **92**,

$$p v^{\frac{1}{16}} = 475, \text{ or } p = \frac{475}{v^{\frac{1}{16}}} = \frac{475}{v^{\frac{1}{16}}}.$$

$$\text{Hence, } \log p = \log 475 - \frac{17}{16} \log 7 = 1.77877.$$

$$p = 60.086 \text{ lb. per sq. in. Ans.}$$

(622) (a) Looking in the table of Properties of Saturated Steam, it is found that for a temperature of  $320.094^\circ$  the pressure is 90 pounds, and for the next lower pressure of the table, 88 pounds, the temperature is  $318.510^\circ$ . Hence, the difference in temperature for a difference of one pound in pressure is

$$\frac{320.094 - 318.510}{2} = .792^\circ.$$

$$320.094^\circ - 320^\circ = .094^\circ = \text{actual difference.}$$

Then 1 lb. :  $.792^\circ :: x$  lb. :  $.094$ , or  $x = .12$  lb., nearly = difference in pressure between  $320^\circ$  and  $320.094^\circ$ .

$$90 - .12 = 89.88 \text{ lb. per sq. in., absolute pressure.}$$

$$89.88 - 14.7 = 75.18 \text{ lb. per sq. in., gauge pressure. Ans.}$$

(b) 110 lb. gauge pressure =  $110 + 14.7 = 124.7$  lb., absolute.

$$\text{Temperature corresponding to } 125 \text{ lb.} = 344.136^\circ.$$

$$\text{Temperature corresponding to } 120 \text{ lb.} = 341.058^\circ.$$

Difference, per pound difference in pressure =

$$\frac{344.136^\circ - 341.058^\circ}{5} = .616^\circ.$$

$$125 - 124.7 = .3 \text{ lb., difference in pressure; } .616 \times .3 = .185^\circ.$$

$$344.136 - .185 = 343.951^\circ. \text{ Ans.}$$

(c) 70 lb., gauge pressure, =  $70 + 14.7 = 84.7$  lb., absolute.

$$\text{Heat of liquid for } 84 \text{ lb.} = 285.414 \text{ B. T. U.}$$

$$\text{Heat of liquid for } 86 \text{ lb.} = 287.096 \text{ B. T. U.}$$

$$\text{Difference per pound} = \frac{287.096 - 285.414}{2} = .841 \text{ B. T. U.}$$

$$.841 \times .7 = .589. \quad 285.414 + .589 = 286.003. \quad \text{B. T. U.}$$

Ans.

Total heat at 86 lb. = 1,178.592 B. T. U.

Total heat at 84 lb. = 1,178.091 B. T. U.

Difference per pound =  $\frac{1,178.592 - 1,178.091}{2} = .25$  B. T. U.

$.25 \times .7 = .175$ .  $1,178.091 + .175 = 1,178.266$  B. T. U.  
Ans.

(d) Latent heat per pound at 66 lb. pressure = 904.443 B. T. U.

Latent heat per pound at 68 lb. pressure = 903.02 B. T. U.

Difference per pound =  $\frac{904.443 - 903.02}{2} = .712$  B. T. U.

$904.443 - .712 = 903.731$  B. T. U., latent heat per pound at 67 lb. pressure.

$903.731 \times 3 = 2,711.193$  B. T. U. Ans.

(623) (a) The isothermal of saturated steam is a straight line parallel to the axis of volumes.

(b) The equilateral hyperbola.

(624) From the table of the Properties of Saturated Steam, the weight of one cubic foot of steam at a pressure of 44 lb. is .106345 lb., and at a pressure of 42 lb. it is .101794 lb.

Difference per pound =  $\frac{.106345 - .101794}{2} = .002276$  lb.

The weight of a cubic foot at 43 lb. pressure is

$.101794 + .002276 = .10407$  lb.

Weight of 38 cu. ft. =  $.10407 \times 38 = 3.95466$  lb. Ans.

(625) See Arts. 1214 and 1215.

(626) See Art. 1206.

To raise 1 pound of water from  $55^\circ$  to  $140^\circ$  requires  $140 - 55 = 85$  B. T. U. Then, to raise 300 pounds of water

through the same range of temperature requires  $85 \times 300 = 25,500$  B. T. U.

60 pounds gauge pressure  $= 60 + 14.7 = 74.7$  pounds, absolute.

Total heat of 1 pound of steam at 74 pounds pressure  $= 1,175.431$  B. T. U.

Total heat of 1 pound of steam at 76 pounds pressure,  $= 1,175.985$  B. T. U.

Difference per pound pressure  $= \frac{1,175.985 - 1,175.431}{2} = .277$  B. T. U.

$.277 \times .7 = .194$ .  $1,175.431 + .194 = 1,175.625$  B. T. U., total heat of 1 pound of steam at an absolute pressure of 74.7 pounds per sq. in.

The total heat (above  $32^\circ$ ) of a pound of water at  $140^\circ$  is  $140 - 32 = 108$  B. T. U.

Hence, each pound of steam on being mixed with water lowers in temperature to  $140^\circ$ , and in so doing gives up  $1,175.625 - 108 = 1,067.625$  B. T. U.

The required amount of steam is

$$\frac{25,500}{1,067.625} = 23.885 \text{ lb. Ans.}$$

(627) The temperature  $256^\circ$  does not appear in the table of the Properties of Saturated Steam. The next lower temperature is found to be  $254.002^\circ$ ; and the next higher,  $257.523^\circ$ . The difference is  $257.523 - 254.002 = 3.521^\circ$ . The difference between the lower temperature and  $256^\circ$  is  $256 - 254.002 = 1.998^\circ$ . The volume of a pound of steam at the lower temperature is 12.68 cu. ft.; and at the higher temperature, 11.98 cu. ft. The difference is  $12.68 - 11.98 = .7$  cu. ft.

The difference between the volume at the lower temperature and the volume at  $256^\circ$  may now be found by proportion

$$3.521 : 1.998 :: .7 : x, \text{ or } x = .397.$$

Hence, the required volume of one pound of steam at  $256^{\circ}$  is

$$12.68 - .397 = 12.283 \text{ cu. ft. Ans.}$$

$$12.283 \times 4\frac{1}{3} = 53.226 \text{ cu. ft. Ans.}$$

(628) See Art. 1192. Specific heat of superheated steam is .48. Hence, to raise 1 pound of superheated steam from  $310^{\circ}$  to  $342^{\circ}$  requires

$$.48 \times (342 - 310) = 15.36 \text{ B. T. U.}$$

To raise 6 pounds through the same range of temperature requires

$$15.36 \times 6 = 92.16 \text{ B. T. U. Ans.}$$

$$\begin{aligned} (629) \quad (a) \quad \log p &= 6.1007 - \frac{2,719.78}{T} - \frac{400,215}{T^2} \\ &= 6.1007 - \frac{2,719.78}{254 + 460} - \frac{400,215}{(254 + 460)^2} \\ &= 1.50643. \\ p &= 32.094 \text{ lb. per sq. in. Ans.} \end{aligned}$$

From the tables,  $p = 32$  lb. per sq. in. for a temperature of  $254^{\circ}$ .

$$\begin{aligned} (b) \quad \log p &= 6.1007 - \frac{2,719.78}{377 + 460} - \frac{400,215}{(377 + 460)^2} = 2.27999, \\ \text{or } p &= 190.54 \text{ lb. per sq. in. Ans.} \end{aligned}$$

From the tables,  $p = 189.212$  lb. per sq. in. for a temperature of  $377^{\circ}$ .

(630) See Arts. 1220 and 1221.

(631) (a)  $H = 1,081.94 + .305 t$ . From the table,  $t = 385.759^{\circ}$ .

$$\text{Hence, } H = 1,081.94 + .305 \times 385.759 = 1,199.596 \text{ B. T. U. Ans.}$$

From the tables,  $H = 1,199.597$ .

(b)  $p = 88$ ;  $t = 318.51^{\circ}$ .

$$\text{Hence, } H = 1,081.94 + .305 \times 318.51 = 1,179.086 \text{ B. T. U. Ans.}$$

From the tables,  $H = 1,179.085$ .

$$(c) \quad p = 37; \quad t = 260.883 + \frac{264.093 - 260.883}{2} = 262.488^{\circ}.$$

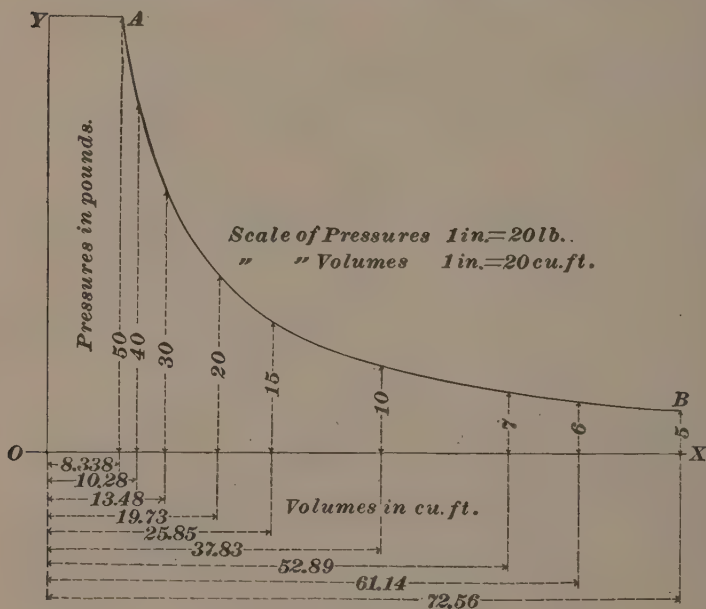
$$H = 1,081.94 + .305 \times 262.488 = 1,161.999 \text{ B.T.U.}$$

Ans.

From the tables,  $H = 1,161.999$ .

(632) See Art. 1293.

(633) See Fig. 49. The lines  $OX$  and  $OY$  are drawn at right angles. The scale of volumes chosen is 20 cu. ft. to the inch, and the scale of pressures 20 lb. to the inch. The vol-



umes corresponding to 50, 40, 30 lb., etc., are found from the steam table, and laid off along  $OX$ . The pressures are then laid off vertically, as shown, forming the required curve  $AB$ .

(634) See Art. 1224.

(635) (a) See Arts. 1252 to 1254.

(b) Clearance  $i = .07$ ; apparent cut-off  $k_1 = \frac{3}{8} = .375$ .

Then, by formula 97, the real cut-off =

$$k = \frac{k_1 + i}{1 + i} = \frac{.375 + .07}{1 + .07} = \frac{.445}{1.07} = .416. \quad \text{Ans.}$$

By formula 96, ratio of expansion,  $e = \frac{1}{k} = \frac{1}{.416} = 2.4.$   
Ans.

(636) By formula 97,  $k = \frac{k_1 + i}{1 + i} = \frac{.625 + .06}{1 + .06} = \frac{.685}{1.06}$ .

By formula 96,  $e = \frac{1}{k} = \frac{1}{\frac{.685}{1.06}} = \frac{1.06}{.685} = 1.547$ .

By formula 99, M. E. P. =  $\frac{.9 P(1 + 2.3 \log e)}{e} - .9 p$ .

$$P = 60 + 14.7 = 74.7 \text{ lb.}; p = 17 \text{ lb.}$$

Then, M. E. P. =  $\frac{.9 \times 74.7 (1 + 2.3 \log 1.547)}{1.547} - .9 \times 17 =$

47.1 lb. per sq. in. Ans.

(637) (a) Using formula 98,

$$\text{I. H. P.} = \frac{P L A N}{33,000} = \frac{47.1 \times \frac{18}{12} \times 11^2 \times .7854 \times 210 \times 2}{33,000} =$$

85.45 H. P. Ans.

(b)  $85.45 \times .83 = 70.92$  actual H. P. Ans.

(c)  $85.45 - 70.92 = 14.53$  friction H. P. Ans.

(638) See Arts. 1232, 1236, 1244, and 1245.

(639) (a) See Arts. 1262 and 1276.

(b) The three principal uses are the following:

1. To find the I. H. P. of the engine.
2. To detect defects in valve setting, and to serve as a guide in setting the valves.
3. To determine, approximately, the steam consumption of the engine.

(640) (a) Work per stroke per sq. in. of piston =

$$3.47 \times \frac{6}{12} \times 40 = 69.4 \text{ ft.-lb.}$$

Area of piston =  $16^2 \times .7854 = 201.0624 \text{ sq. in.}$

Then, total work per stroke =  $69.4 \times 201.0624 = 13,953.73 \text{ ft.-lb.}$  Ans.

(b) 120 rev. per min. =  $120 \times 2 = 240 \text{ strokes per min.}$

$$\text{Then, H. P.} = \frac{13,953.73 \times 240}{33,000} = 101.48. \quad \text{Ans.}$$

(641) Admission, cut-off, release, and compression are all too late, and the back pressure is excessive. Admission, release, and compression may be made earlier by increasing the angular advance; cut-off may be made earlier by adding lap to the valve; the back pressure can be reduced only by reducing the resistance to the passage of the exhaust steam; that is, by enlarging the exhaust port or the exhaust pipe, or both.

(642) Assuming a mechanical efficiency of 80%, the I. H. P. of the engine must be  $\frac{120}{.80} = 150$ .

The probable M. E. P. may be found from formula 99.

$$\begin{aligned} \text{M. E. P.} &= \frac{.9 P(1 + 2.3 \log e)}{e} - .9 p = \\ &= \frac{.9 \times 84.7(1 + 2.3 \log 4)}{4} - .9 \times 3 = 42.75 \text{ lb. per sq. in.} \end{aligned}$$

Assume 550 feet per minute as a fair piston speed. We have, then,  $P = 42.75$ , and  $LN = \text{piston speed} = 550$ .

Substituting, in formula 98, I. H. P. =  $\frac{P L A N}{33,000}$ ,  $150 = \frac{42.75 \times 550 \times A}{33,000}$ , or  $A = \frac{150 \times 33,000}{42.75 \times 550} = 210.52 \text{ sq. in.}$ , the

area of the piston. The diameter is, consequently,  $\sqrt{\frac{210.52}{.7854}} = 16\frac{1}{2}"$ , nearly. Assuming the stroke to be 42 in., the number of revolutions, from formula 100, is



$$R = \frac{6S}{L} = \frac{6 \times 550}{42} = 78.57.$$

This is a fair number of revolutions for a Corliss engine. Hence, an engine  $16\frac{1}{2}'' \times 42''$ , making  $78\frac{1}{2}$  rev. per min., will do the required work.

(643) (a) 60 pounds, gauge pressure,  $= 60 + 14.7 = 74.7$  lb., absolute; 2 lb. above atmosphere  $= 2 + 14.7 = 16.7$  lb., absolute.

Temperature of steam at 74.7 lb. pressure is, from the table of the Properties of Saturated Steam,

$$306.526 + \left( \frac{308.344 - 306.526}{2} \right) .7 = 307.162^\circ.$$

Temperature of steam at 16.7 is

$$216.347 + (219.452 - 216.347) .7 = 218.521^\circ. \quad \text{Then,}$$

$$T_1 = 307.162^\circ + 460^\circ = 767.162^\circ$$

and

$$T_2 = 218.521^\circ + 460^\circ = 678.521^\circ.$$

$$\text{Thermal efficiency} = \frac{T_1 - T_2}{T_1} = \frac{767.162 - 678.521}{767.162} = .1155 = 11.55\%. \quad \text{Ans.}$$

(b) In this case, the absolute pressure of the entering steam is  $90 + 14.7 = 104.7$  pounds per sq. in., and the pressure of the exhaust steam 3 pounds per sq. in., absolute.

The temperature corresponding to the former pressure is from the table  $= 331.169 - \left( \frac{331.169 - 327.625}{5} \right) .3 = 330.956^\circ$ .

The temperature corresponding to the latter pressure is  $141.654^\circ$ . Hence,  $T_1$  is  $330.956^\circ + 460^\circ = 790.956^\circ$ , and  $T_2$  is  $141.654^\circ + 460^\circ = 601.654^\circ$ .

$$\text{Thermal efficiency} = \frac{790.956 - 601.654}{790.956} = .2393 = 23.93\%. \quad \text{Ans.}$$

(644) (a) Using formula 100,

$$L = \frac{6S}{R} = \frac{6 \times 540}{150} = 21.6''. \quad \text{Ans.}$$

$$(b) R = \frac{6S}{L} = \frac{6 \times 900}{2\frac{1}{2} \times 12} = 180 \text{ rev. per min.} \quad \text{Ans.}$$

(645) The M. E. P. is found as shown in Fig. 50.

The middle ordinates are drawn as explained in Art. 1159.

These ordinates are measured and multiplied by the scale of the spring, which reduces them from inches to pounds.

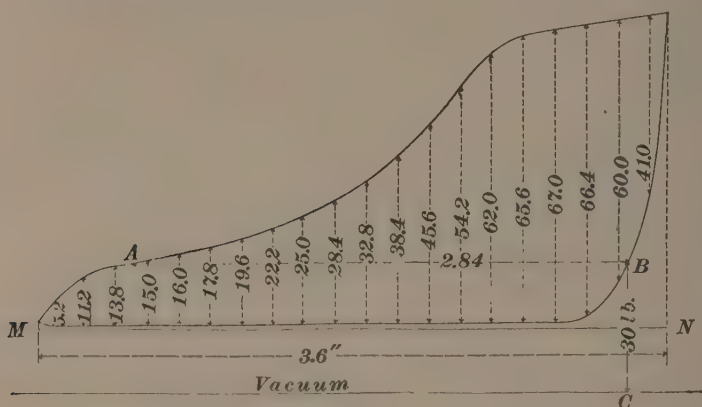


FIG. 50.

In the figure the sum of the 20 ordinates is 707.2 pounds. The mean ordinate, or, what is the same thing, the M. E. P., is, therefore,  $\frac{707.2}{20} = 35.36$  lb. Draw the vacuum line at a

distance of  $\frac{14.7}{40} = .3675$ " below the atmospheric line  $MN$ .

Choose the point  $A$  near the point of release, and draw  $AB$  parallel to  $MN$ . The height  $BC$  of this line above the vacuum line is  $\frac{3}{4}$ "; therefore, the absolute pressure at  $A$  or

$B$  is  $\frac{3}{4} \times 40 = 30$  pounds. The length  $AB = l = 2.84$ ", and the length of the diagram  $L$  is 3.6". The weight of a cu. ft. of steam at 30 pounds pressure, absolute, is .074201 lb.

Substituting these values in formula 101,

$$Q = \frac{13,750 \text{ I. H. P.}}{PL} = \frac{13,750 \times 2.84 \times .074201}{35.36 \times 3.6} =$$

22.76 lb. per I. H. P. per hour. Ans.

(646) (a) See Arts. **1293** and **1294**.

(b) See Arts. **1314** and **1315**.

(647) Area of high-pressure cylinder =  $19^2 \times .7854$  sq. in.

Area of low-pressure cylinder =  $32^2 \times .7854 = 804.25$  sq. in.

Ratio of area of high-pressure cylinder to area of low-pressure cylinder =  $\frac{19^2 \times .7854}{32^2 \times .7854} = \frac{19^2}{32^2} = \frac{361}{1,024}$ .

M. E. P. of high-pressure cylinder reduced to low-pressure cylinder =  $52 \times \frac{361}{1,024} = 18.332$  lb. per sq. in.

Total M. E. P. reduced to low-pressure cylinder =  
 $18 + 18.332 = 36.332$  lb. per sq. in.

(a) Substituting now in formula **98**,

$$\text{I. H. P.} = \frac{PLAN}{33,000} = \frac{36.332 \times \frac{30}{12} \times 804.25 \times 120 \times 2}{33,000} = 531.27. \quad \text{Ans.}$$

(b) Since the stroke is the same for each cylinder, the ratio of the work done by the two cylinders is proportional to the ratio of the two M. E. P.'s reduced to the low-pressure cylinder. Hence, the ratio of the work done in the high-pressure cylinder to that done in the low-pressure cylinder is  $18.332:18 = 1.0184$ . Ans.

(648) (a) See Art. **1276**.

(b) 1. Decrease the angular advance.

2. Increase the angular advance.

3. Lower the boiler pressure or decrease the number of revolutions.

4. Raise the boiler pressure or increase the number of revolutions.

(649) (a) The points desired are shown in Fig. 51. To locate the point of cut-off, prolong the steam and expansion

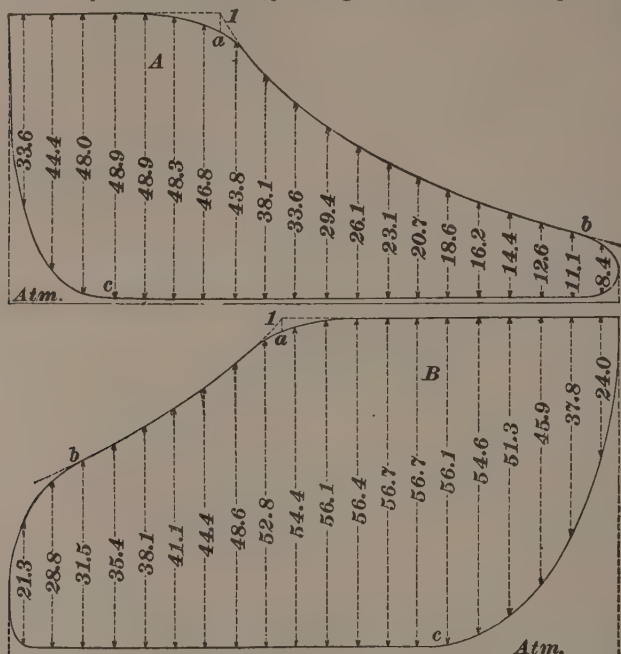


FIG. 51.

lines till they intersect, as at *1*. From *1* drop the perpendicular *1 a*, and *a* will be the point of cut-off.

The point of release may be located by prolonging the expansion curve, and noting the point where the actual curve departs from it, as shown at *b*. The point of compression *c* is easily located.

(b) The M. E. P. of the two diagrams are found as shown in the figure. The length of each diagram is divided into 20 equal parts, and ordinates are erected at the middle points of the divisions. The lengths of these ordinates multiplied by the scale of the spring used, in this case,  $1'' = 30 \text{ lb.}$ , added together and divided by 20 gives the required M. E. P. The

M. E. P. of diagram  $A$  is found to be 30.75 lb. per sq. in., and the M. E. P. of diagram  $B$  is found to be 44.6 lb. per sq. in. Ans.

(650) Using formula 106,

$$S = .0944 W = .0944 \times 675 \times 26\frac{1}{2} = 1,688.58 \text{ sq. ft. Ans.}$$

(651) Area of piston =  $.7854 \times 30^2 = 706.86$  sq. in. The

piston speed is, from formula 100,  $S = \frac{LR}{6} = \frac{48 \times 80}{6} =$

640 ft. per min.; hence, the velocity of the crank-pin ( $= v_0$ )

is  $\frac{640 \times 3.1416}{2} = 1,005.3$  ft. per min.  $= \frac{1,005.3}{60} = 16.755$  ft.

per sec. The ratio  $n$  between the radius of the fly-wheel and

length of crank is  $\frac{10}{2} = 5$ . Substituting now in formula 107,

$$W = \frac{A H g}{n^2 E V_0^2} = \frac{706.86 \times 88 \times 32.16}{5^2 \times \frac{1}{80} \times 16.755^2} = 14,251.92 \text{ lb. Ans.}$$

(652) (a) Use formula 98.

$$\text{I. H. P.} = \frac{P L A N}{33,000}, \text{ or } A = \frac{33,000 \text{ I. H. P.}}{P L N} = \frac{33,000 \times 1,200}{42 \times \frac{1}{2} \times 70 \times 2} =$$

1,924.2 sq. in., area of low-pressure piston. Diameter of

low-pressure cylinder  $= \sqrt{\frac{1,924.2}{.7854}} = 49\frac{1}{2}$ . Ans.

(b) Since the stroke is the same for both cylinders, their volumes are proportional to the areas of their pistons.

Hence, using formula 103,

$$\frac{V}{v} = \frac{\text{area of low-pressure piston}}{\text{area of high-pressure piston}} = \frac{E}{2.72}, \text{ or area of high-pres}$$

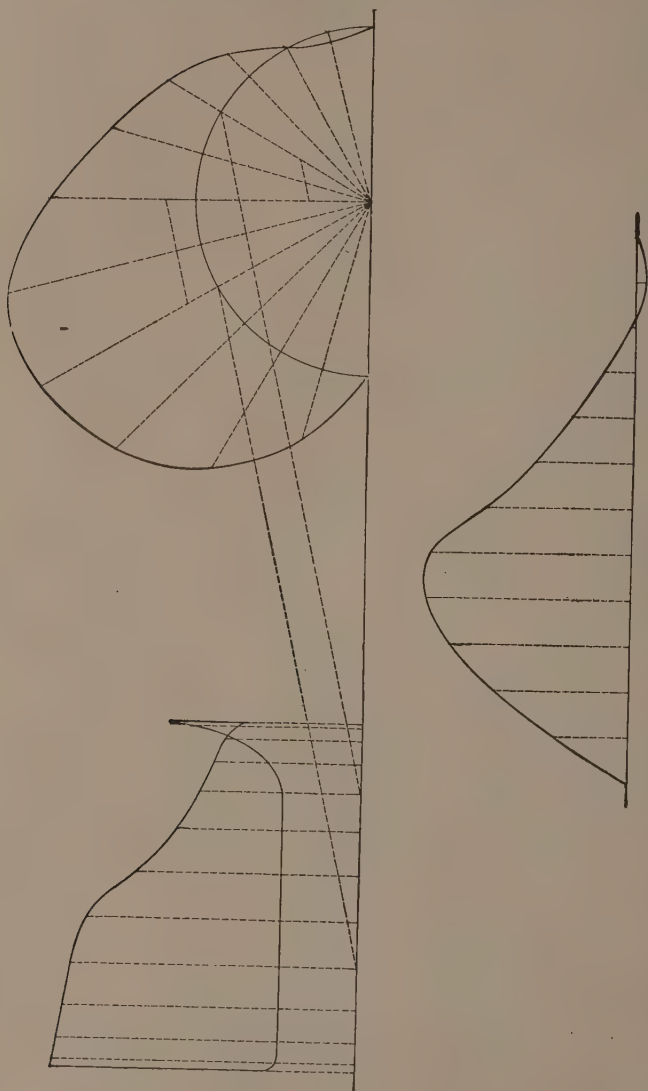
$$\text{sure piston} = \frac{2.72 \times 1,924.2}{5.5} = 951.6 \text{ sq. in.}$$

The corresponding diameter is

$$\sqrt{\frac{951.6}{.7854}} = 34\frac{13}{16}, \text{ or say } 34\frac{7}{8}. \text{ Ans.}$$

Using formula 104,

$$\frac{V}{v} = \frac{\text{area of low-pressure piston}}{\text{area of high-pressure piston}} = \sqrt{E} = \sqrt{5.5}.$$



Hence, area of high-pressure piston  $= \frac{1,924.2}{\sqrt{5.5}} = 820.48$  sq. in.

The corresponding diameter is  $32\frac{5''}{16}$ , say  $32\frac{3''}{8}$ . Ans.

(653) (a) By formula **102**,  $E = \frac{eV}{v}$ , or  $e = \frac{Ev}{V}$ ; but, by formula **103**,  $\frac{V}{v} = \frac{E}{2.72}$ , or  $E = 2.72\frac{V}{v}$ . Substituting this value of  $E$  in **102**, we have,  $e = 2.72\frac{V}{v} \cdot \frac{v}{V} = 2.72$ . Hence, the real cut-off  $= \frac{1}{e} = \frac{1}{2.72} = .368$ . Ans.

(b) From formula **104**,  $\frac{V}{v} = \sqrt{E}$ , or  $\frac{v}{V} = \frac{1}{\sqrt{E}}$ .

Substituting this value of  $\frac{v}{V}$  in formula **102**, above,

$$e = \frac{E}{\sqrt{E}} = \sqrt{E} = \sqrt{5.5} = 2.345.$$

Real cut-off  $= \frac{1}{e} = \frac{1}{2.345} = .426$ . Ans.

(654) See Art. **1330**.

(655) The construction is shown in Fig. 52. It is precisely similar to the construction shown in Art. **1313**, and need not be further described.

(656) The total heat of steam at  $4\frac{1}{2}$  pounds pressure is, from the steam tables,

$$\frac{1,128.641 + 1,131.462}{2} = 1,130.051 \text{ B. T. U.}$$

Now, using formula **105**,

$$W = \frac{H - t_s + 32}{t_1 - t_2} = \frac{1,130.051 - 130 + 32}{130 - 55} = 13.76 \text{ lb. Ans.}$$

(657) See Art. **1291**.

(658) (b) Using formula **98**, I. H. P.  $= \frac{PLAN}{33,000}$ , or

$$LA = \frac{33,000 \text{ I. H. P.}}{PN} = \frac{33,000 \times 42}{36.3 \times 155 \times 2}$$

$L$  = stroke in feet.

$12 L$  = stroke in inches.

From the conditions of the problem,  $12 L = 1 \frac{1}{3} d$ , when  $d$  is taken in inches, or  $L = \frac{1}{9} d$ .  $A = .7854 d^2$ . Substituting these values of  $L$  and  $A$ ,

$$\frac{1}{9} d \times .7854 d^2 = \frac{.7854 d^3}{9} = \frac{33,000 \times 42}{2 \times 36.3 \times 155},$$

$$\text{or } d = \sqrt[3]{\frac{33,000 \times 42 \times 9}{36.3 \times 155 \times 2 \times .7854}} = 11.22'' \text{ nearly, or, say } 11 \frac{1}{4}''.$$

Ans.

$$(a) \text{ Stroke} = 1 \frac{1}{3} d = 11 \frac{1}{4} \times 1 \frac{1}{3} = 15'', \text{ nearly. Ans.}$$

(c) Using formula 100,

$$S = \frac{LR}{6} = \frac{15 \times 155}{6} = 387.5 \text{ ft. per min. Ans.}$$

(659) (a) Area of piston,  $.7854 \times 22^2 = 380.1336$  sq. in.

Total pressure on piston =  $380.1336 \times 72 = 27,369.62$  lb.

At the beginning of the stroke, the piston rod, connecting-rod, and crank lie in the same straight line, and, consequently, the total pressure on the piston is transmitted to the crank-shaft.

(b) In this case the total pressure on the piston is  $380.1336 \times 65 = 24,708.68$  lb., which is also the horizontal pressure on the crank-pin.

Then, the pressure on the crank-shaft is  $24,708.68 \times \cos 60^\circ = 12,354.34$  lb. Ans.

(c) The tangential pressure is  $24,708.68 \times \sin 60^\circ = 21,398.46$  lb. Ans.

(660) See Art. 1311.

The mean ordinate should be  $34.6 \times \frac{2}{3.1416} = 22.03$  lb. per sq. in. Ans.



(661) Diameter of drivers =  $80'' = \frac{80}{12} = 6\frac{2}{3}$  ft.

Circumference of drivers =  $6\frac{2}{3} \times \pi = 20.944$  ft.

60 miles per hour = 1 mile per min.

One mile contains 5,280 ft. Hence, the number of revolutions of the driver per min. is  $\frac{5,280}{20.944}$ .

Area of piston =  $.7854 \times 19^2 = 283.53$ .

Now, using formula 98,

$$\text{I. H. P.} = \frac{PLAN}{33,000} = \frac{52.5 \times \frac{24}{12} \times 283.53 \times \frac{5,280}{20.944} \times 2}{33,000} = 454.86.$$

Since there are two cylinders, the total horsepower =  $454.86 \times 2 = 909.72$  I. H. P. Ans.

(662) (a) As shown in Fig. 53, the diameter of the path described by the eccentric is the travel of the valve, 5".

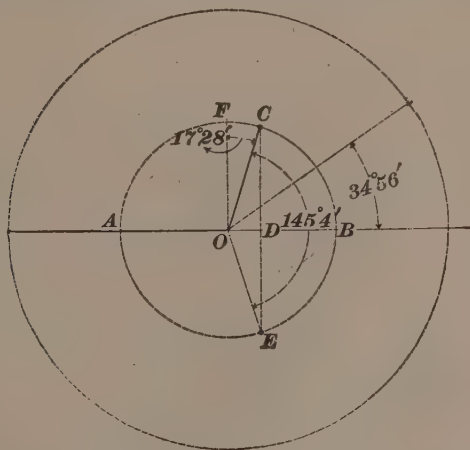


FIG. 53.

The eccentric crank must be in a position  $OC$ , so that, upon

dropping the perpendicular  $CD$  upon  $AB$ , the distance  $OD$

will equal the lap  $\frac{3}{4}$ ". Then,  $\cos COD = \frac{OD}{OC} = \frac{\frac{3}{4}}{\frac{1}{2\sqrt{2}}} = .3$ .

The angle whose cosine is .3 is  $72^\circ 32'$ , nearly. Hence,  $COD = 72^\circ 32'$ , and the angular advance  $COF = 90^\circ - COD = 90 - 72^\circ 32' = 17^\circ 28'$ .

(b) When cut-off occurs the valve must be in the same position as it was at the beginning of the stroke, but moving in the opposite direction. Hence, the center of the eccentric must be at  $E$  vertically below  $C$ , and must have passed through the angle  $COE = 2COB = 2 \times 72^\circ 32' = 145^\circ 4'$ . Therefore, the crank has moved  $145^\circ 4'$  from the dead-center position, and now makes an angle of  $\frac{145^\circ 4'}{2} = 72^\circ 32'$ , with  $AB$ , the diameter through the dead points.

$$(663) \quad (a) \text{ Efficiency} = \frac{12.325}{15.36} = .8024 = 80.24\%. \quad \text{Ans.}$$

$$(b) \text{ Area of piston} = .7854 \times 9^2 = 63.617 \text{ sq. in.}$$

$$\text{Stroke} = 12'' = 1 \text{ foot.}$$

$$\text{Using formula 98, I.H.P.} = \frac{PLAN}{33,000}, \text{ or}$$

$$P = \frac{\text{I.H.P.} \times 33,000}{LAN} = \frac{15.36 \times 33,000}{1 \times 63.617 \times 240 \times 2} = 16.6 \text{ lb.}$$

(664) See Arts. 1223 and 1224.

(665) The construction is shown in Fig. 54. Choose a suitable length for the diagram, say 3 inches. Draw the atmospheric line  $MN$ . Choose a scale of pressures, say 40 pounds per inch, and draw the vacuum line  $OX$  parallel to  $MN$  and  $\frac{14.7}{40} = .3675''$  below it. On  $OX$  lay off the length of the diagram  $AB = 3''$ . This length represents to some scale the volume of the cylinder, and 7% of this length must then represent to the same scale the clearance. Therefore,

from  $A$ , lay off  $AO$  equal to  $7\%$  of  $AB = 3 \times .07 = .21''$ , and from  $O$  draw  $OY$  perpendicular to  $OX$ . Lay off  $MC = \frac{70}{40} = 1\frac{3}{4}$  to represent the boiler pressure, and through  $C$  draw  $CE$  parallel to  $OB$ . The number of expansions is 3. Hence, lay off  $CD = \frac{1}{3}OB$ , and  $D$  will be the point of cut-off. Through  $D$ , draw the equilateral hyperbola  $DF$ .

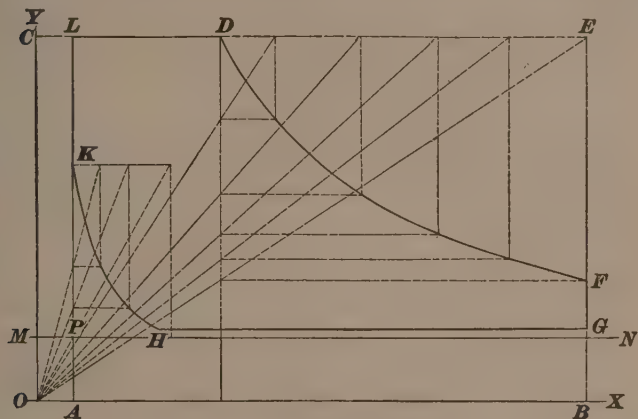


FIG. 54.

as explained in Art. 1161, taking  $O$  as the point from which to draw the radial lines.  $DF$  is the expansion line. The back pressure is 2 lb. above the atmosphere. Hence, the line  $GH$  drawn parallel to  $MN$  and  $\frac{2}{40} = \frac{1''}{20}$  above 1 will represent the back-pressure line of the diagram. Since the steam is compressed to 40 lb., the point where compression ends may be found by measuring  $PK = \frac{40}{40} = 1''$  above  $MN$ . Through  $K$ , the equilateral hyperbola  $KH$  is drawn in the same manner as  $DF$ . Draw  $KL$  perpendicular to  $MN$ , and the diagram is finished.

(666) See Art. 1308.

(667) To obtain an idea of the condensation of the steam in the cylinder. There is generally more condensation at cut-off than at release, on account of re-evaporation, and if the steam consumption be calculated from both points, the difference will tell more or less, approximately, the amount of condensation at cut-off.

(668) The data assumed will, of course, depend largely upon circumstances. Suppose the engine to be non-condensing, and to run with a piston speed of 300 feet per minute, and use steam at a boiler pressure of 35 lb. The mechanical efficiency will probably be about .94, which requires the engine to develop  $\frac{340}{.94} = 361$  I. H. P. Assuming the number of expansions to be 2.5, the probable M. E. P. is, from formula 99,  $M. E. P. = \frac{P \cdot 2.3 \log 2.5}{2.5} = \frac{.9 \times 89.7 (1 + 2.3 \log 2.5)}{2.5} = 46.55$ .

Now, using formula 98,  $I. H. P. = \frac{P \cdot L \cdot A \cdot N}{33,000}$  or  $A = \frac{33,000 I. H. P.}{P \cdot L \cdot N}$ . But  $L \cdot N = \text{piston speed} = 300$  ft.

Hence,  $A = \frac{33,000 \times 361}{46.55 \times 300} = 814.46$  sq. in. = area of piston.

The diameter corresponding to this area is  $31\frac{1}{2}$  in.

For this diameter a fair stroke would be 30 in. the number of revolutions being from formula 100,

$$R = \frac{3.5}{L} = \frac{3.5 \times 300}{40} = 26.$$

The engine would be made  $31\frac{1}{2}$  x 30 in. and run at 26 rev. per min. Ans.

(669) The scale of the spring should be a general not less than  $\frac{1}{2}$  of the boiler pressure.

(2)  $\frac{54}{2} = 27$ ; hence, a 30 spring should be used.

(b)  $\frac{115}{2} = 57\frac{1}{2}$ ; hence, a 60 spring should be used.

(c)  $1.834'' \times 40 = 73.36$  lb. per sq. in. Ans.

(670) Weight of condensing water per pound of steam  
 $= \frac{13,580}{906}$ .

Total heat of steam at an absolute pressure of 7 pounds is, from the table, 1,135.908. Substituting in formula **105**,

$W = \frac{H - t_3 + 32}{t_1 - t_2}$ , or  $t_3 = H + 32 - W(t_1 - t_2)$ , we obtain

$$t_3 = 1,135.908 + 32 - \frac{13,580}{906} (120 - 52) = 148.66^\circ. \text{ Ans.}$$

(671) The areas of the three pistons are proportional to the squares of their respective diameters. Hence, the M. E. P. of the high-pressure cylinder reduced to the low-pressure

cylinder is  $72 \times \frac{27^2}{66^2} = 12.05$  lb. per sq. in. The M. E. P. of the intermediate cylinder reduced to the low-pressure cylinder is

$$40 \times \frac{42^2}{66^2} = 16.2 \text{ lb. per sq. in.}$$

The total M. E. P. reduced to the low-pressure cylinder is, consequently,  $12.05 + 16.2 + 16.5 = 44.75$  lb. per sq. in.

Area of low-pressure piston =  $.7854 \times 66^2 = 3,421.2$  sq. in.

(a) Substituting, now, in formula **98**,

$$\text{I. H. P.} = \frac{PLAN}{33,000} = \frac{44.75 \times 4 \times 3,421.2 \times 70 \times 2}{33,000} = 2,598. \text{ Ans.}$$

(b) The work done in each cylinder is proportional to the M. E. P. of the cylinder reduced to the low-pressure cylinder. Hence, the percentage of the total work done in the

high-pressure cylinder is  $\frac{12.05}{44.75} = .269 = 26.9\%$ . Ans. The

percentage of the work done in the intermediate cylinder is  $\frac{16.2}{44.75} = .362 = 36.2\%$ . Ans. Lastly, the percentage of the

work done in the low-pressure cylinder is  $\frac{16.5}{44.75} = .369 = 36.9\%$ . Ans.

(672) See Art. 1287.

(673) The number of expansions is determined from formulas 97 and 96,

$$k = \frac{k_1 + i}{1 + i} = \frac{.25 + .025}{1 + .025} = \frac{.275}{1.025}$$

$$e = \frac{1}{k} = \frac{1}{\frac{.275}{1.025}} = \frac{1.025}{.275} = 3.727.$$

(a) The M. E. P. may now be found from formula 99.

$$\text{M. E. P.} = \frac{.9 P(1 + 2.3 \log e)}{e} - .9 p =$$

$$\frac{.9 \times 98.7(1 + 2.3 \log 3.727)}{3.727} - .9 \times 3 = 52.455 \text{ lb. per sq. in.}$$

Ans.

(b) Using formula 98, I. H. P. =  $\frac{PLAN}{33,000}$ , or  $A = \frac{33,000 \times \text{I. H. P.}}{PLN} = \frac{33,000 \times 120}{52.455 \times 500} = 151 \text{ sq. in.}$  The required diameter is, therefore,  $\sqrt{\frac{151}{.7854}} = 13\frac{7}{8}''$ . Ans.

(674) Since the gauge pressure is 93 lb., the absolute pressure is  $93 + 14.7 = 107.7 \text{ lb.}$  Substituting the logarithm of 107.7 in formula 90,

$$2.03222 = 6.1007 - \frac{2,719.78}{T} - \frac{400,215}{T^2}$$

Clearing of fractions and transposing,

$$4.06848 T^2 - 2,719.78 T = 400,215.$$

As this is an affected quadratic, it may be solved by the rule given in algebra; hence, dividing by the coefficient of  $T^2$ ,  $T^2 - 668.5 T = 98,369.66$ . Completing the square  $T^2 - 668.5 T + 111,723.2 = 210,092.86$ . Extracting square root,  $T - 334.25 = 458.359$ , or  $T = 792.609^\circ$ . Therefore,  $792.609 - 460 = 332.609^\circ$ . Ans.

(675) See rule in Art. 1246, and the answer to question 662.

(676) The volume discharged in 1 stroke is

$$\frac{18^2 \times .7854 \times 24}{1,728} \text{ cu. ft.,}$$

and the volume discharged in 1 minute is

$$\frac{18^2 \times .7854 \times 24 \times 175 \times 2}{1,728}$$

Formula **93** gives the work in foot-pounds which is done in 1 stroke; hence, if multiplied by the number of strokes per minute and divided by 33,000, the result will be the horsepower. The pressure is 62.4 lb. Substituting these values of the pressure and volume, in formula **93**, and dividing by 33,000, we have

$$\frac{144 \times 62.4 \times 18^2 \times .7854 \times 24 \times 175 \times 2}{1,728 \times 33,000} = 336.825 \text{ horsepower.}$$

Ans.

(677) Dividing the diagram into 10 equal parts, and measuring the ordinates drawn at the middle of these divisions, the sum of their lengths for diagram *A* is 7.16", for diagram *B*, 7.24", and for diagrams *C* and *D*, 4.68" and 4.72", respectively. Dividing these sums for *A* and *B* by 10 and multiplying by 60, the scale of spring, we have,

$$\text{for } A, 7.16 \times \frac{60}{10} = 42.96 \text{ lb. per sq. in.};$$

$$\text{for } B, 7.24 \times \frac{60}{10} = 43.44 \text{ lb. per sq. in.}$$

Adding and dividing by 2, the mean effective pressure for the high-pressure cylinder is found to be  $\frac{42.96 + 43.44}{2} = 43.2$  lb. per sq. in.

The M. E. P. for the low-pressure cylinder is,

$$\text{for } C, 4.68 \times \frac{30}{10} = 14.04 \text{ lb. per sq. in.};$$

$$\text{for } D, 4.72 \times \frac{30}{10} = 14.16 \text{ lb. per sq. in.}$$

Adding and dividing by 2, the M. E. P. for the low-pressure cylinder is  $\frac{14.04 + 14.16}{2} = 14.1$  lb. per sq. in.

Reducing the M. E. P. of the high-pressure cylinder to the area of the low-pressure piston, we have  $43.2 \times \frac{13^2 \times .7854}{20^2 \times .7854} = 18.252$  lb. per sq. in.

Hence,  $14.1 + 18.252 = 32.352$  lb. per sq. in. = the M. E. P. if the work was all done in the low-pressure cylinder.

$$\text{Therefore, I. H. P.} = \frac{PLAN}{33,000} = \frac{32.352 \times \frac{15}{12} \times 20^2 \times .7854 \times 230 \times 2}{33,000} = 177.1 \text{ I. H. P. Ans.}$$

(678) Fig. 55 shows diagram *A* and diagram *D* drawn as mentioned in Art. **1305**; that is, the scale of pressures

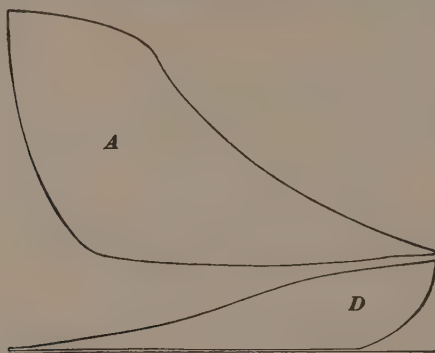


FIG. 55.

on diagram *D* has been reduced to 60, the same as on diagram *A*. In Fig. 56 the length of diagram *A* has been reduced in the proportion of the ratio of the volume of the high-pressure cylinder to that of the low-pressure cylinder. By reading Arts. **1304** and **1305**, the student should have no trouble in drawing the diagrams by aid of the above figures.

(679) Using a scale divided into thirtieths of an inch, and locating for this case a point  $\frac{28''}{30}$  above the vacuum line



(which should be drawn previous to this), we draw through this point a line parallel to the atmospheric line. The length of the portion of this line included between the

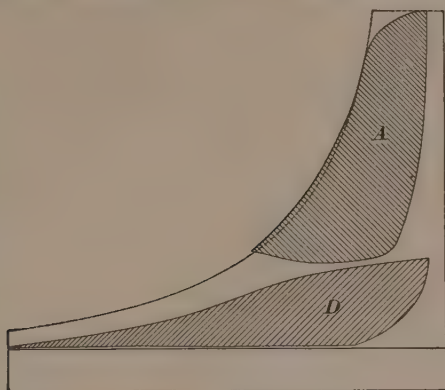


FIG. 56.

bounding lines of the diagram is 2.95", and the absolute pressure which it represents is 28 lb. The whole length of the diagram is  $3\frac{1}{2}$ ". The weight of a cubic foot of steam at this pressure is, from the table of the Properties of Saturated Steam, .069545 lb. The M. E. P. was found to be 30.75 lb. per sq. in., in example 649.

Substituting these values in formula **101**,

$$Q = \frac{13,750 \times 2.95 \times .069545}{30.75 \times 3.5} = 26.21 \text{ lb. per I. H. P. per}$$

hour. Ans.

(680) For (a) and (b) see Art. **1292**. (c) No. The stroke may be so short that the piston speed will be low, although the rotative speed is high.

(681) The absolute pressure =  $123 + 14.7 = 137.7$  lb. Logarithm of 137.7 = 2.13893. Substituting in formula **90**,

$$2.13893 = 6.1007 - \frac{2,719.78}{T} - \frac{400,215}{T^2}$$

Clearing of fractions and transposing,  $3.96177 T^2 - 2,719.78 T = 400,215$ .

Solving this equation for  $T$  in the same manner as was done in example 674,  $T = 811.49^\circ$ , or  $t = 811.49 - 460 = 351.49^\circ$ . Ans.

(682) Since, according to formula 98,

$$\text{I. H. P.} = \frac{PLAN}{33,000}, P = \frac{\text{I. H. P.} \times 33,000}{LAN}$$

Substituting the values given in the present example,

$$P = \frac{300 \times 33,000}{\frac{18}{12} \times 22^2 \times .7854 \times 200 \times 2} = 43.406 \text{ lb. per sq. in.} \quad \text{Ans.}$$

(683) See answer to question 675.

(684) Drawing and uniting the lines  $st$  and  $vt$  and  $tr$  of diagrams  $A$  and  $B$ , respectively, the diagram shown at (a), Fig. 57, is drawn. (Fig. 57 is not drawn to scale.) Dividing the part  $rst$  into 10 equal parts, and measuring the ordinates drawn at the middle of those parts, the sum of their lengths is  $7.78''$ , and the average length (mean ordinate) is  $7.78 \div 10 = .778''$ . The length of a line parallel to the atmospheric line included between the point  $t$  and the line  $sr$  is  $2.23''$ . Hence, area of  $rst = .778 \times 2.23 = 1.7349$  sq. in. Dividing  $vtu$  into 5 equal parts, the sum of the middle ordinates is  $1.8''$ .  $1.8 \div 5 = .36'' =$  mean ordinate of  $vtu$ . Length from point  $t$  to line  $vu = .37''$ . Area of  $vtu = .36 \times .37 = .1332$  sq. in. Subtracting area  $vtu$  from area  $rst$ ,  $1.7349 - .1332 = 1.6017$  sq. in. The length  $ru = 2.6''$ . Hence, the mean pressure urging the piston ahead is  $\frac{1.6017 \times 60}{2.6} = 36.96$  lb. per sq. in. Ans.

(685) This example is worked like the previous examples where the horsepower is to be found from the diagrams. Dividing the length of the diagrams into ten equal parts, and measuring the middle ordinates, their sum for diagram

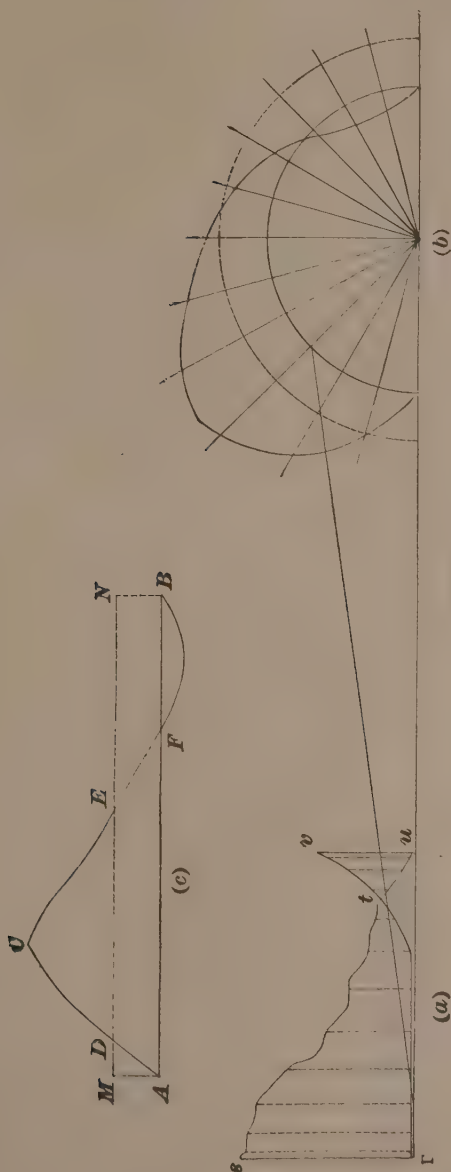


FIG. 57.

$A$  is found to be 6.04", and for  $B$ , 6.62". The mean ordinate for  $A = \frac{6.04}{10} = .604$ , and for  $B$ ,  $\frac{6.62}{10} = .662$ . Hence, the

$$\text{total M. E. P.} = \frac{.604 + .662}{2} \times 60 = 37.98 \text{ lb. per sq. in.}$$

$$\text{I. H. P.} = \frac{37.98 \times 1 \times 13^3 \times .7854 \times 300 \times 2}{33,000} = 91.66. \quad \text{Ans.}$$

(686) Drawing a line parallel to the atmospheric line, and at a distance from the vacuum line corresponding to a pressure of 40 lb., absolute, the length included between the bounding lines of diagram  $A$  is 1.46", and the length between the bounding lines of diagram  $B$  is 1.72". The length of both diagrams is 2.6". The weight of a cubic foot of steam at an absolute pressure of 40 lb. is .097231 lb. The M. E. P. for card  $A = .604 \times 60 = 36.24$  lb., and for card  $B$ ,  $.662 \times 60 = 39.72$  lb. (See example 685.) Substituting in formula **101**, we have, for card  $A$ ,

$$Q = \frac{13,750 \times 1.46 \times .097231}{36.24 \times 2.6} = 20.716 \text{ lb.,}$$

and for card  $B$ ,

$$Q = \frac{13,750 \times 1.72 \times .097231}{39.72 \times 2.6} = 22.267 \text{ lb.}$$

Taking the average of both cards,

$$Q = \frac{20.716 + 22.267}{2} = 21.49 \text{ lb. per I. H. P. per hour.} \quad \text{Ans.}$$

(687) In Fig. 57 is shown the solution to this question. The cut is not drawn to scale, and the student should re-draw it full size. By referring to Art. **1313**, the student should have no difficulty.

Find the areas of  $ACF$  and  $FB$ ; subtract the smaller from the larger, and divide by the length  $AB$ ; the result is the height  $AM$ . Draw  $MN$  parallel to  $AB$ ; also the dotted semicircle, at a distance from the full semicircle equal to  $AM$ .

(688) Compute the area of  $DCE$  in the usual manner; for the present case it equals .78 sq. in. The stroke

of the engine =  $12'' = 1$  ft. and the crank-pin travels in one stroke a distance =  $\frac{1 \times 3.1416}{2} = 1.5708$  feet. The length

$AB = 4.08''$ . Consequently,  $1''$  of length on  $AB = \frac{1.5708}{4.08} =$

.385 ft. of crank-pin travel. Since the vertical scale of pressures is  $1'' = 60$ ,  $H$ , in formula **107**, =  $.78 \times 60 \times .385 = 18.018$  lb. per sq. in. of piston area. Substituting in

formula **107**, we have  $W = \frac{A H g}{n^2 E v^2}$

$$= \frac{13^2 \times .7854 \times 18.018 \times 32.16}{5^2 \times \frac{1}{50} \times \left( \frac{300 \times 2 \times 1 \times 3.1416}{2 \times 60} \right)^2} = 623 \text{ lb.} \quad \text{Ans.}$$



# STEAM BOILERS.

(QUESTIONS 859-958.)

(859) See Arts. **1698** and **1702**.

(860) See Arts. **1764** to **1791**.

(861) Applying formula **168**,

$$t = \sqrt{\frac{p l d}{1,600,000}} = \sqrt{\frac{80 \times 15 \times 12 \times 3}{1,600,000}} = \frac{3}{16}'' \text{, nearly. Ans.}$$

(862) Applying formula **177**,

$$d = 1.13 \sqrt{\frac{A p}{T}} = 1.13 \sqrt{\frac{12 \times 13\frac{1}{2} \times 125}{6,000}} = 2\frac{1}{16}'' \text{, nearly. Ans.}$$

(863) Applying formula **184**,

$$t = h \sqrt{\frac{p}{k}} = 8 \sqrt{\frac{150}{40,000}} = .49'' \text{, say } \frac{1}{2}'' \text{. Ans.}$$

(864) (a) Using formula **190**,

$$h = 14,500 \times .80 + 62,032 \left( .08 - \frac{.06}{8} \right) = 16,097.32 \text{ B.T.U. Ans.}$$

(b) Using formula **189**,

$$W = 11.6 \times .80 + 34.8 \left( .08 - \frac{.06}{8} \right) = 11.8 \text{ lb. Ans.}$$

(865) Since the number of B. T. U. contained in the gases is directly proportional to the temperature,  $600^\circ - 250^\circ = 350^\circ$  may be considered to represent the amount of heat saved. Then,

$$350 \div 2,800 = .125 = 12.5\% \text{. Ans.}$$

(866) From Table 41, the factor of evaporation for  $120^\circ$  feed and 80 lb. pressure = 1.131; for  $120^\circ$  feed and 90 lb. pressure = 1.133; hence, the factor for  $120^\circ$  feed and 85 lb. pressure is evidently 1.132. In a similar manner it is found

that for  $130^\circ$  feed and 85 lb. pressure, the factor is 1.121. Consequently, for a difference of  $10^\circ$  in the feed, difference in the factors is  $1.132 - 1.121 = .011 = .0011$  for a difference of  $1^\circ$ .  $127^\circ - 120^\circ = 7^\circ$ , and  $.0011 \times 7 = .0077 =$  difference for a difference of  $7^\circ$ . Hence, the factor for  $127^\circ$  feed and 85 lb. pressure  $= 1.132 - .0077 = 1.1243$ , and  $\frac{28,930 \times 1.1243}{34.5 \times 10} = 94.3$  H. P. Ans.

(867) From the table of the Properties of Saturated Steam, the latent heat of steam at 80 lb. gauge pressure is 886.59, and the temperature is  $323.71$ . Applying formula **204**, and substituting,

$$Q = \frac{1}{886.59} \left[ \frac{360}{22} (110 - 44) - (323.71 - 110) \right] = 97.7\%. \text{ Ans.}$$

(868) From the steam table, the volume of a pound of steam at 75 lb. gauge pressure is 4.811 cu. ft. Then, the area of the cross-section of the pipe must be

$$\frac{7,200 \times 4.811 \times 144}{4,000 \times 60} = 20.78 \text{ sq. in.,}$$

and the diameter not less than  $5\frac{3}{16}$ ". Ans.

(869) This example might be worked by applying formula **186** for each pressure; but since there is a constant difference of 5 lb. between any two consecutive pressures, there will also be a constant difference between any two consecutive graduations, and the example may be worked as follows: Applying formula **186** for a pressure of 40 lb.,

$$d = \frac{4.5 (40 \times 12.5664 - 8.5) - 21 \times 19}{107} = 17.05". \text{ Ans.}$$

Applying again for 60 lb.,

$$d = \frac{4.5 (60 \times 12.5664 - 8.5) - 21 \times 19}{107} = 27.62". \text{ Ans.}$$

Then,  $\frac{27.62 - 17.05}{4} = 2.64\frac{1}{4}" =$  distance which weight must be moved in order to produce a difference of 5 lb. per



sq. in. in the blow-off pressure. Hence, for a blow-off pressure of 45 lb.,

$$d = 17.05 + 2.64\frac{1}{4} = 19.69". \quad \text{Ans.}$$

For 50 lb.,  $d = 17.05 + 2.64\frac{1}{4} \times 2 = 22.34". \quad \text{Ans.}$

And for 55 lb.,  $d = 17.05 + 2.64\frac{1}{4} \times 3 = 24.98". \quad \text{Ans.}$

(870) See Art. **1695**,

(871) (a) 4 ft. 3 in. = 4.25 ft. Total force exerted along one seam =  $\frac{12 \times 4.25 \times 144 \times 80}{2} = 293,760 \text{ lb.} \quad \text{Ans.}$

(b) Total force along a girth seam =  $4.25^2 \times .7854 \times 80 \times 144 = 163,426 \text{ lb.} \quad \text{Ans.}$

(872) (a) to (d) See Arts. **1736** to **1739**.

(e) The double-riveted butt joint. (See formula **171**.)

(873) Applying formula **179**,

$$a = .885 d \sqrt{\frac{T}{p}} = .885 \times 1\frac{3}{4} \sqrt{\frac{9,000}{140}} = 12.42", \text{ say } 12\frac{1}{2}". \quad \text{Ans.}$$

(874) (a) and (b) See Arts. **1764** and **1765**.

(c) See Art. **1770**.

(d) See Art. **1772**.

(875) (a) See Art. **1804**.

(b) See Art. **1805**. (c)  $400 \times .4 = 160 \text{ lb.} \quad \text{Ans.}$

(d) See Art. **1805**.

(876) Using formula **193**,

$$p = H \left( \frac{7.6}{T_a} - \frac{7.9}{T_c} \right),$$

$$\text{or } H = \frac{p}{\frac{7.6}{T_a} - \frac{7.9}{T_c}} = \frac{.77}{\frac{7.6}{460 + 60} - \frac{7.9}{460 + 580}} = 110 \text{ ft.} \quad \text{Ans.}$$

(877) See Art. **1833**.

(878) Using formula **205**,

$$Q = \frac{W + R}{W + R + w} = \frac{20.5 + \frac{2}{16}}{20.5 + \frac{2}{16} + \frac{14}{16}} = 95.9\%. \quad \text{Ans.}$$

(879) See Art. **1894**.

(880) See Arts. **1698** to **1703**.

(881) (a) Force =  $\frac{65 \times 4\frac{1}{2} \times 12}{2} = 1,755 \text{ lb.} \quad \text{Ans.}$

(b) Force =  $1,755 \div 2 = 877.5 \text{ lb.} \quad \text{Ans.}$

(882) See Art. **1740**.

(883) Applying formula **178**,

$$d = 1.13 a \sqrt{\frac{p}{T}} = 1.13 \times 3.75 \sqrt{\frac{128}{4,000}} = .758", \text{ say } \frac{3}{4}" \quad \text{Ans.}$$

(884) From Table 41, the factor of evaporation for a feed temperature of  $65^\circ$  and a pressure of 85 lb. is 1.189; for a feed temperature of  $200^\circ$  and the same steam pressure, it is 1.049. Hence,

$$\text{gain} = \frac{1.189 - 1.049}{1.189} = .118 = 11.8\%. \quad \text{Ans.}$$

(885) Applying formula **190**,

$$h = 14,500 \times .94 + 62,032 \left( .01 - \frac{.02}{8} \right) = 14,095.24 \text{ B. T. U.}$$

$$14,095.24 \div 966.1 = 14.59 \text{ lb.} \quad \text{Ans.}$$

(886) Applying formula **192**,

$$p = H \left( \frac{7.6}{T_a} - \frac{7.9}{T_c} \right) = 135 \left( \frac{7.6}{460 + 65} - \frac{7.9}{460 + 420} \right) = \frac{3}{4}" \text{ of water, nearly.} \quad \text{Ans.}$$

(887) See Arts. **1832** and **1813**.

(888) See Arts. **1859** to **1867**.

(889) See Arts. **1897** and **1898**.

(890) See Arts. **1707** to **1709** and Art. **1879**.

(891) Applying formula **165** and taking  $\frac{S_1}{f} = 9,500$ ,

$$t = \frac{f p d}{2 S_1 y} = \frac{1 \times 110 \times 38}{2 \times 9,500 \times .60} = .37'' = \frac{3}{8}'' \quad \text{Ans.}$$

(892) See Arts. **1740** and **1741**.

(893) Using formula **178**,

$$d = 1.13 a \sqrt{\frac{p}{T}} = 1.13 \times 4.5 \sqrt{\frac{160}{8,000}} = .719'', \text{ say } \frac{3}{4}'' \quad \text{Ans.}$$

(894) (a)  $120 \times 30 = 3,600$  lb. of steam per hour.

Applying formula **188**,

$$a = \frac{.5 w}{p + 10} = \frac{.5 \times 3,600}{70 + 10} = 22.5 \text{ sq. in.} \quad \text{Ans.}$$

(b)  $22.5 \times 70 = 1,575$  lb. Ans.

(895) See Art. **1802**.

(896) (a) Applying formulas **197** and **194**,

$$d = 13.54 \sqrt{E} + 4 = 13.54 \sqrt{\frac{.3 \text{ H. P.}}{\sqrt{H}}} + 4 =$$

$$13.54 \sqrt{\frac{.3 \times 700}{\sqrt{105}}} + 4 = 65.3'' \quad \text{Ans.}$$

(b) Applying formulas **196** and **194**,

$$S = 12 \sqrt{\frac{.3 \times 700}{\sqrt{105}}} + 4 = 58.3'' \quad \text{Ans.}$$

(897) Using formula **202**, in which  $W = 150 \times 34.5$ ,

$$G = \frac{W}{F e} = \frac{150 \times 34.5}{16 \times 10.25} = 31.55 \text{ sq. ft.} \quad 31.55 \times 36 = 1,136 \text{ sq. ft.} \quad \text{Ans.}$$

(898) See Arts. **1868** to **1873**.

(899) Applying formula **200**,

$F = 2.25 \sqrt{H} = 2.25 \sqrt{135} = 26.14$  lb. of coal per sq. ft. of grate per hour. Then,  $26.14 \times 3.5 \times 5 \times 10 = 4,575$  lb.

Ans.

(900) See Arts. **1717** to **1721**.

(901) Applying formula **165**,

$$t = \frac{f p d}{2 S_1 y} = \frac{4 \times 140 \times 13 \times 12}{2 \times 64,000 \times .72} = \frac{15}{16}'' \quad \text{Ans.}$$

(902) Applying formula **170**,

$$h = \left(1 + \frac{7d}{4t}\right) d = \left(1 + \frac{7}{4} \times \frac{.75}{.375}\right) \times .75 = 3\frac{3}{8}'' \quad \text{Ans.}$$

(b) Applying formula **172**,

$$d = t + \frac{3}{8} = \frac{3}{8} + \frac{3}{8} = \frac{3}{4}'' \quad \text{Ans.}$$

(c) Applying formula **173**,

$$y = \frac{h - d}{h} = \frac{3\frac{3}{8} - \frac{3}{4}}{3\frac{3}{8}} = .78 = 78\% \quad \text{Ans.}$$

(903) Using formula **179**,

$$a = .885 d \sqrt{\frac{T}{p}} = .885 \times 1 \sqrt{\frac{6,000}{150}} = 5.6'' \quad \text{Ans.}$$

(904) See Arts. **1773** to **1782**.

(905)  $11.6 \times .95 = 11.02$  lb. of air required per pound of coal. Then, since 1 lb. of air at  $62^\circ$  has a volume of 13.14 cu. ft., the total number of cubic feet to be furnished per minute =

$$11.02 \times 1\frac{1}{2} \times 13.14 \times \frac{4 \times 6 \times 12}{60} = 1,042.6 \text{ cu. ft.} \quad \text{Ans.}$$

(906) (a) From Table 38, 632 H. P. Ans.

(b) Applying formulas **195** and **194**, we have, since 3 ft. 8" = 44",

$$\text{H. P.} = 3.33 E \sqrt{H} = 3.33 (A - .6 \sqrt{A}) \sqrt{H} =$$

$$3.33 \left( \frac{44^2}{144} - .6 \sqrt{\frac{44^2}{144}} \right) \sqrt{80} = 336 \text{ H. P.} \quad \text{Ans.}$$

(907) From Table 41, the factor of evaporation for a feed temperature of  $120^\circ$  and a steam pressure of 105 lb. gauge = 1.137; and for  $200^\circ$  feed and 105 lb. gauge = 1.054. Then,

$$\text{gain} = \frac{1.137 - 1.054}{1.137} = .073 = 7.3\% \quad \text{Ans.}$$

(908) See Arts. 1876 and 1877.

(909) (See Art. 1900.)  $300 \times 30 = 9,000$  lb. of water required per hour. Adding 15% for emergencies and 20% for leakage of water past the piston, etc.,  $9,000 + 9,000 (.15 + .20) = 12,150$  lb. per hour  $= \frac{12,150}{62.5} = 194.4$  cu. ft. per hour. Assuming the pump to make 40 strokes per minute, the displacement per stroke  $= \frac{194.4 \times 1,728}{60 \times 40} = 140$  cu. in. Taking the stroke as twice the diameter,

$$d^3 \times .7854 \times 2d = 140, \text{ or } d = \sqrt[3]{\frac{140}{2 \times .7854}} = 4.47'', \text{ say } 4\frac{1}{2}''.$$

Then, stroke  $= 4\frac{1}{2} \times 2 = 9''$ . Ans. Ans.

(910) See Art. 1716.

(911) In Art. 1366 it is stated that a cylinder is twice as strong against transverse rupture as it is against longitudinal rupture. Since, in example 901, the efficiency of the joint is 72%, the relative strengths of the two seams are  $\frac{2 \times .72}{1 \times .72} = \frac{2}{1}$ , i.e., the girth seam is twice as strong as the longitudinal seam.

(912) See Arts. 1744 and 1745.

(913) Applying formula 180,

$$d = 1.13 \sqrt{\frac{A p}{T \cos B}} = 1.13 \sqrt{\frac{35 \times 80}{6,000 \cos 18^\circ}} = .791'', \text{ say } \frac{13}{16}''.$$

Ans.

(914) Applying formula 185,

$$W = \frac{a(pA - W_1) - W_2 c}{d} = \frac{4(110 \times 5^2 \times .7854 - 8) - 12 \times \frac{40}{2}}{40} = 209.2 \text{ lb.}$$

Ans.

(915) See Arts. 1806 and 1807.

(916) The easiest and most accurate way to solve this example is as follows: Let  $H$ ,  $T_a$ , and  $T_c$  represent the height

and absolute temperatures before the economizer is introduced, and  $H'$ ,  $T_a$ , and  $T_c'$  the same quantities after the economizer has been introduced. Then, since  $p$  is the same in both cases,

$$H \left( \frac{7.6}{T_a} - \frac{7.9}{T_c} \right) = H' \left( \frac{7.6}{T_a} - \frac{7.9}{T_c'} \right).$$

Solving this equation for  $H'$ ,

$$H' = H \left[ \frac{(7.6 T_c - 7.9 T_a) T_a T_c'}{(7.6 T_c' - 7.9 T_a) T_a T_c} \right].$$

Substituting for the letters their values and canceling the two factors  $T_a$ ,

$$H' = 90 \left[ \frac{(7.6 \times 1,080 - 7.9 \times 520) 730}{(7.6 \times 730 - 7.9 \times 520) 1,080} \right] = 173.2 \text{ ft.}$$

Hence, the additional height =  $173.2 - 90 = 83.2$  ft. Ans.

(917) See Art. 1839.

Applying formula 203, we have

$$(a) \frac{(H - t + 32)}{966.1} = \frac{1,182.233 - 113 + 32}{966.1} = 1.1399. \text{ Ans.}$$

$$(b) \frac{1,188.110 - 73 + 32}{966.1} = 1.1874. \text{ Ans.}$$

$$(c) \frac{1,190.989 - 87 + 32}{966.1} = 1.1758. \text{ Ans.}$$

$$(d) \frac{1,168.626 - 158 + 32}{966.1} = 1.0792. \text{ Ans.}$$

(918) See Arts. 1878 and 1879.

(919) See Art. 1896.

(920) See Arts. 1722 to 1728.

(921) (a) and (b) See Art. 1750.

(c) The spherical vessel. Art. 1366.

(922) See Arts. 1748 and 1749.

(923) Using formula 181,

$$d = \sqrt[3]{\frac{p h l^2}{6,000}} = \sqrt[3]{\frac{120 \times 8 \times 33^2}{6,000}} = 5.585'', \text{ say } 5\frac{5}{8}''. \text{ Ans.}$$

(924) Applying formula **186**,

$$d = \frac{a(pA - W_1) - W_2 c}{W} = \frac{4(110 \times 5^2 \times .7854 - 8) - 12 \times 20}{265} \\ = 31.6''. \quad \text{Ans.}$$

(925) See Art. **1808**.

(926) Applying formula **200**,

$$(a) \quad 2.25 \sqrt{H} = 2.25 \sqrt{80} = 20 \frac{1}{8} \text{ lb. per sq. ft. of grate per hour.} \quad \text{Ans.}$$

$$(b) \quad 2.25 \sqrt{115} = 24 \frac{1}{8} \text{ lb. per sq. ft. of grate per hour.} \quad \text{Ans.}$$

(927) See Arts. **1840** to **1852**.

(928) See Art. **1880**.

(929) (a) At 65 lb. gauge pressure the latent heat of steam is (see steam table) 895.296 B. T. U., and the temperature is 311.605°. Applying formula **204**,

$$Q = \frac{1}{l} \left[ \frac{W}{w} (t_2 - t_1) - (t - t_2) \right] = \\ \frac{1}{895.296} \left[ \frac{327}{24} (120 - 40) - (311.605 - 120) \right] = 1.00346. \quad \text{Ans.}$$

(b) The answer to (a) shows that the steam is superheated, and the number of degrees of superheat can be determined by means of the expression given in Art. **1853**. Thus,

$$\frac{(Q - 1)l}{.48} = \frac{(1.00346 - 1)895.296}{.48} = 6.5^\circ, \text{ nearly.} \quad \text{Ans.}$$

(930) See Arts. **1725**, **1726**, and **1714**.

(931) Applying formula **167**, and substituting 12,000 for  $\frac{S_1}{f}$ ,

$$p = \frac{2tS_1y}{fd} = \frac{2 \times \frac{5}{16} \times 12,000 \times .66}{42} = 118 \text{ lb. per sq. in.} \quad \text{Ans.}$$

(932) Solving formula **174** for  $p$ , and substituting,

$$p = \frac{3 t^2 S}{2 r^2} = \frac{3 \times \left(\frac{1}{2}\right)^2 \times 10,000}{2 \times 24^2} = 6.5 \text{ lb. per sq. in.} \quad \text{Ans.}$$

(933) Applying formula **182**,

$$p = \frac{6,000 d^3}{h l^2} = \frac{6,000 \times 7.5^3}{10 \times 42^2} = 143.5 \text{ lb. per sq. in.} \quad \text{Ans.}$$

(934) See Arts. **1783** to **1791**.

(935) See Arts. **1820**, **1812**, and **1823**.

(936) Applying formula **199**,

$$F = 1.5 \sqrt{H} - 1, \text{ or } H = \left(\frac{F+1}{1.5}\right)^2 = \left(\frac{14+1}{1.5}\right)^2 = 100 \text{ ft.} \quad \text{Ans.}$$

(937) (a) See Art. **1841**.

(b) Total heat of 1 lb. of steam at 60 lb. gauge pressure = 1,175.625 B. T. U. Heat units required to vaporize the water at 52° into steam at 60 lb. gauge = 1,175.625 - 52 + 32 = 1,155.625 B. T. U.

$$\text{Efficiency} = \frac{1,155.625 \times 175,000}{19,000 \times 13,500} = 78.8\% \quad \text{Ans.}$$

(938) See Art. **1866**.

(939) See Art. **1861**.

(940) See Art. **1712**.

(941) See solution to (b), example 929.

$$\frac{(Q-1)l}{.48} = \frac{(1.0148-1)884.98}{.48} = 27.29^\circ \quad \text{Ans.}$$

(942) Solving formula **174** for  $t$  and applying,

$$t = \sqrt{\frac{2 r^2 p}{3 S}} = \sqrt{\frac{2 \times 17^2 \times 75}{3 \times 5,000}} = 1.7'' \quad \text{Ans.}$$

(943) Applying formula **183**,

$$p = \frac{k t^2}{h^2} = \frac{28,000 \times \left(\frac{5}{16}\right)^2}{4.5^2} = 135 \text{ lb. per sq. in.} \quad \text{Ans.}$$



(944) See Arts. **1794** and **1800**.

$$(945) \quad \frac{175 \times 40}{60} = 116\frac{2}{3} \text{ lb. of coal per minute.}$$

Applying formula **191**,

$$\text{H. P.} = \frac{p W V}{33,000 \gamma} = \frac{12 \times 116\frac{2}{3} \times 230}{33,000 \times .625} = 15.61 \text{ H.P. Ans.}$$

$$(946) \quad \frac{3,000}{9\frac{1}{2} \times 15} = 21 \text{ sq. ft. Ans.}$$

$$(947) \quad (a) \quad \frac{175,000 \times 1,155.625}{966.1} = 209,331 \text{ lb. Ans.}$$

$$(b) \quad 209,331 \div 19,000 = 11.02 \text{ lb. per pound of coal. Ans.}$$

$$(c) \quad 209,331 \div (19,000 \times .93) = 11.85 \text{ lb. per pound of combustible. Ans.}$$

$$(d) \quad \text{Horsepower} = \frac{209,331}{34.5 \times 22} = 275.8 \text{ H.P. Ans.}$$

(948) See Arts. **1881** to **1883** and **1698** to **1703**.

(949) Applying formula **190** to find the heat of combustion,  $h = 14,500 \times .643 + 62,032 \left( .042 - \frac{.100}{8} \right) = 11,153.5$  B. T. U. Heat required to change 1 lb. of water at  $100^\circ$  into steam having a temperature of  $240^\circ$  is found from the steam table to be 1,087.14 B. T. U. Hence,  $\frac{11,153.5}{1,087.14} = 10.26$  lb. Ans.

(950) From Table 41, the factor of evaporation for  $55^\circ$  feed and 40 lb. gauge pressure is 1.187. Consequently,  $\frac{935 \times 1.187}{34.5} = 32.2$  H. P. nearly. Ans.

(951) Applying formula **166**,

$$p = \frac{2 t S_1}{f d} = \frac{2 \times \frac{3}{8} \times 12,000}{30} = 300 \text{ lb. per sq. in. Ans.}$$

(952) Applying formula **176**,

$$t = \frac{a}{2} \sqrt{\frac{p}{S}} = \frac{20}{2} \sqrt{\frac{30}{12,000}} = \frac{1}{2}'' \quad \text{Ans.}$$

(953) Applying formula **184**,

$$t = h \sqrt{\frac{p}{k}} = 4 \sqrt{\frac{110}{24,000}} = .2712'', \text{ say } \frac{9}{32}'' \quad \text{Ans.}$$

(954)  $18 - 11.8 = 6.2$  lb. free air.  $8 + 6 = 14\%$  of hydrogen and oxygen. Then,  $H - \frac{O}{8} = .08 - \frac{.06}{8} = .0725 = 7.25\%$  free hydrogen. Therefore, percentage of water =  $14 - 7.25 = 6.75\%$ , and the composition of the fuel may be written  $C = 80\%$ ,  $H = 7.25\%$ , water  $6.75\%$ , and ash  $6\%$ . The products of combustion are :

Carbonic acid .....  $80 \times 3.67 = 2.936$  lb.

Water (steam) ..  $.0675 + .0725 \times 9 = 0.72$  lb.

Nitrogen .....  $11.8 \times .77 = 9.086$  lb.

Free air ..... =  $6.2$  lb.

Ash ..... =  $0.06$  lb.

Total ..... =  $19.00$  lb.

Then, as in Art. **1802**,

$$t = \frac{16,097.32 - .72 \times 966.1}{2.936 \times .217 + .72 \times .4805 + 9.086 \times .2438 + 6.2 \times .2375} = 3,297^\circ \quad \text{Ans.}$$

(955) See Arts. **1816** and **1814**.

(956)  $\frac{28,930 \times 1.1243}{3,120} = 10.43$  lb. of water per pound of coal from and at  $212^\circ$ . Ans.

(957) See Art. **1853**.

(958) See Arts. **1887** to **1893**.

Applying formula **206**,

$$t = 0.0001 p d + \frac{1}{8} = 0.0001 \times 105 \times 4 \frac{1}{2} + \frac{1}{8}'' = .172'',$$

say  $\frac{11}{64}''$ . Ans.

# LOCOMOTIVES.

(QUESTIONS 478-547.)

(478) (a) See Art. 826.

(b) See Art. 832.

(c) See Art. 825.

(479) Using rule 153, Art. 813,

$$W_s = 5 \quad T = 5 \times 11,420 = 57,100 \text{ lb.} \quad \text{Ans.}$$

(480) See Art. 931.

(481) See Art. 893.

(482) According to rule 157, Art. 869, the total heating surface is

$$H = .175 \, d^2 l = .175 \times 17^2 \times 24 = 1,214 \text{ sq. ft.}$$

As in Art. 873, using rule 160,

$$H_2 = 1,214 \times \frac{7}{8} = 1,062 \text{ sq. ft.}$$

The inside diameter of a  $2\frac{1}{4}$ " tube is 2.054 (see Table 30, Art. 874), hence, using rule 162, Art. 875,

$$n = \frac{H_2}{.2618 \, d \, L} = \frac{1,062}{.2618 \times 2.054 \times 11.75} = 168 \text{ tubes.} \quad \text{Ans.}$$

(483) See Arts. 856 and 857.

(484) Using rule 152, Art. 812,

$$d = \sqrt{\frac{W_s D}{5 p l}} = \sqrt{\frac{120,000 \times 48}{5 \times 120 \times 24}} = 20". \quad \text{Ans.}$$

(485) Using rule 166, Art. 929,

$$F = \frac{.65 \, w}{n} = \frac{.65 \times 132,000}{8} = 10,725 \text{ lb.} \quad \text{Ans.}$$

(486) See Arts. 891 and 892.

(487) See Art. 855.

(488) Using rule 161, Art. 874,

$$H = .2618 d n L = .2618 \times 1.804 \times 140 \times 12.5 = 826.5 \text{ sq. ft.} \quad \text{Ans.}$$

(489) Using rules 155 and 156, Arts. 823 and 824,

$$\frac{3}{.85} \times 1.2 = 4.235'' = 4\frac{1}{4}'', \text{ say.} \quad \text{Ans.}$$

(490) See Art. 867.

(491) See Arts. 841 and 840.

(492) See Art. 819.

(493) See Art. 808.

(494) Using rule 144, Art. 804,

$$R = 7\frac{1}{2} (W_1 + W_2) = 7\frac{1}{2} (623 + 22) = 4,837.5 \text{ lb.} \quad \text{Ans.}$$

(495) According to formula 164, Art. 882,

$$t = .00015 D P + .175 \sqrt{D} = .00015 \times 20 \times 160 + .175 \sqrt{20} = 1.2626'', \text{ say } 1\frac{1}{4}''.$$

Hence, according to statement in the paragraph just above formula 164, Art. 882, the required thickness is

$$1\frac{1}{4}'' - \frac{1}{8}'' = 1\frac{1}{8}''. \quad \text{Ans.}$$

(496) (a) According to rule 165, Art. 897,

$$a = \rho \frac{A}{c} = \frac{180 \times 19^2 \times .7854}{6,000} = 8.51 \text{ sq. in.} \quad \text{Ans.}$$

(b) Since  $\frac{L}{d} = 20$ ,  $d = \frac{L}{20} = \frac{94}{20} = 4.7''$ , say  $4\frac{3}{4}''$ . Ans.

$$\text{Hence, } \frac{8.51}{4.7} = 1.81'', \text{ say } 1\frac{13}{16}''. \quad \text{Ans.}$$

(497) See Art. 893.

(498) See Art. 857.

(499) See Art. 806.

(500) See Art. 796.

(501) Using rule 158, Art. 870,

$$G = \frac{7}{500} \times \frac{11,560}{500} = 29.12 \text{ sq. ft. Ans.}$$

(502) Using rule 152, Art. 812,

$$d = \sqrt{\frac{W_s D}{5 p l}} = \sqrt{\frac{48,000 \times 72}{5 \times 119 \times 20}} = 17'' \text{ Ans.}$$

(503) Using rule 146, Art. 806,

$$W_s = 5R = 5 \times 9,000 = 45,000 \text{ lb. Ans.}$$

(504) Using rule 166, Art. 929,

$$F = \frac{.75 w}{n} = \frac{.75 \times 110,000}{6} = 13,750 \text{ lb. Ans.}$$

(505) Using rule 154, Art. 822,

$$\text{cross-sectional area} = \frac{18^2 \times .7854 \times 96 \times 170}{2,700 \times 100} = 15.38 \text{ sq. in.}$$

Take width of frame 4" throughout; then, depth of upper frame brace =  $\frac{15.38}{4} = 3.84''$ ;  $3\frac{3}{4}''$  will suffice. Ans.

Now, by rule 155,

depth of lower frame brace =  $3\frac{3}{4} \times .85 = 3.19''$ ; say  $3\frac{1}{4}''$  for thimble. Ans.

Or,  $3\frac{3}{4} \times .70 = 2.625$ ; say  $2\frac{5}{8}''$  for cap. Ans.

Depth of front splice, by rule 156, =  $3\frac{3}{4} \times 1.2 = 4.5$ ;  $4\frac{1}{2}''$ ; Ans.

(506) See Art. 889.

(507) (b) Applying rule 158, Art. 870,

$$G = \frac{p d^2 l}{600 D} = \frac{85 \times 22^2 \times 26}{600 \times 50} = 35.65 \text{ sq. ft. Ans.}$$

(a) Taking the direct heating surface as 7 times the grate surface,

$$H_1 = 35.65 \times 7 = 250 \text{ sq. ft., nearly. Ans.}$$

(c) Applying rule **160**, Art. **873**,

$$H_2 = 250 \times 7 = 1,750 \text{ sq. ft.} \quad \text{Ans.}$$

In this case it would be better to use 8 instead of 7; doing so,

$$H_2 = 250 \times 8 = 2,000 \text{ sq. ft.}$$

(508) See Arts. **851** and **852**.

(509) Using rule **151**, Art. **811**,

$$d = \sqrt{\frac{TD}{pl}} = \sqrt{\frac{16,000 \times 60}{124 \times 24}} = 18". \quad \text{Ans.}$$

(510) See Art. **887**.

(511) Using rule **145**, Art. **806**,

$$A = \frac{1}{5} W_s = \frac{1}{5} \times 54,000 = 10,800 \text{ lb.} \quad \text{Ans.}$$

(512) (See description in Arts. **918**, etc.) Expressed very briefly, air is stored under pressure in the train pipe and equalizing reservoir through the working of the air pump. On turning the lever of the engineer's brake valve, a part of the air escapes from the train pipe, reducing the pressure therein, and allowing the air in the equalizing reservoir to operate the brakes.

(513) Using rule **157**, Art. **869**,

$$H = .175 d^2 l = .175 \times 22^2 \times 26 = 2,202 \text{ sq. ft.} \quad \text{Ans.}$$

(514) Using rule **149**, Art. **809**,

$$T = \frac{p d^2 l}{D} = \frac{172 \times 22^2 \times 26}{50} = 43,289 \text{ lb.} \quad \text{Ans.}$$

NOTE.—This value is too high, since it would require a weight on the drivers of 216,200 lb., but it indicates what the tractive power would be if the adhesion were high enough.

(515) See Art. **843**.

(516) Applying rule **154**, Art. **822**,

$$\text{area} = \frac{20^2 \times .7854 \times 160}{2,800} = 17.95 \text{ sq. in.,}$$

$$\text{and depth} = \frac{17.95}{4.25} = 4.22", \text{ say } 4\frac{1}{4}". \quad \text{Ans.}$$

(517) Using rule **145**, Art. **806**,

$$A = \frac{1}{5} W_s = \frac{1}{5} \times 73,000 = 14,600 \text{ lb.} \quad \text{Ans.}$$

(518) Using rule **149**, Art. **809**,

$$T = \frac{p d^2 l}{D} = \frac{156 \times 18^2 \times 24}{78} = 15,552 \text{ lb.} \quad \text{Ans.}$$

(519) See Arts. **915** to **917**.

(520) See Art. **820**.

(521) See Arts. **883** and **884**.

(522) See Art. **842**.

(523) See Art. **868**.

(524) See Art. **805**.

(525) See Art. **831**.

(526) Using rule **153**, Art. **813**,

$$W_s = \frac{5 p d^2 l}{D} = \frac{5 \times 138 \times 16^2 \times 20}{60} = 58,880 \text{ lb.} \quad \text{Ans.}$$

(527) See Arts. **801** to **803**.

(528) Total weight to be placed on the drivers =  $14,000 \div 5 = 70,000$  lb. In Art. **806** it is stated that from 10,000 to 15,000 lb. may be placed on each driver when using 65 to 80 lb. rails. The difference in loads is 5,000 lb.; the difference in weight of rails is 15 lb.; the difference between the 65-lb. and 70-lb. rails is 5 lb. Hence, we have the proportion,  $15 : 5 :: 5,000 : x$ , or  $x = 1,666\frac{2}{3}$  lb. Therefore, with 70 lb. rails,  $10,000 + 1,666\frac{2}{3} = 11,666\frac{2}{3}$  lb. may be placed on each driver. Now, applying rule **147**, Art. **806**,

$$N = \frac{W}{w} = \frac{70,000}{11,666\frac{2}{3}} = 6 \text{ drivers.} \quad \text{Ans.}$$

(529) See Arts. **815** to **817**.

(530) See Art. **838**.

(531) See Arts. **862** and **863**.

(532) See Art. **806**.

(533) See Art. 797.

(534) Applying rule 163, Art. 881,

$$a = \frac{PA}{5,000N} = \frac{180 \times 19^2 \times .7854}{5,000 \times 20} = .51 \text{ sq. in.}$$

According to Table 31, Art. 881,  $a = .55$  sq. in. for a 1" stud; hence, 1" stud bolts will probably be used. Ans.

(535) See Art. 896.

(536) See Arts. 859 and 860.

(537) See Art. 893.

(538) See Art. 836.

(539) See Art. 876.

(540) See Art. 814.

(541) See Arts. 865 to 867.

(542) Using formula 164, Art. 882,

$$t = .00015 DP + .175\sqrt{D} = .00015 \times 17 \times 170 + .175\sqrt{17} = 1.155", \text{ say } 1\frac{5}{8}". \text{ Ans.}$$

(543) See Arts. 898 and 899.

(544) Using rule 148, Art. 807,

$$D = \frac{336.134 S}{n} = \frac{336.134 \times 45}{252} = 60", \text{ very nearly. Ans.}$$

(545) See Arts. 816 and 818.

(546) Using rule 144, Art. 804,

$$R = 7\frac{1}{2} (W_1 + W_2) = 7\frac{1}{2} \times 1,200 = 9,000 \text{ lb. Ans.}$$

(547) See Art. 839.



# LOCOMOTIVES.

(QUESTIONS 548-592.)

(548) Area of piston  $= .7854 \times 17^2 = 227$  sq. in., nearly.

Using rule **167**, Art. **935**,  $w = \frac{A \times S}{6,000 \times l} = \frac{227 \times 660}{6,000 \times 16\frac{1}{2}} = 1\frac{1}{2}$  in., nearly. Ans.

(549) Rule **168**, Art. **937**, is applied in this case.

Width of exhaust port  $= 1\frac{3}{8} + 2\frac{3}{4} + \frac{1}{16} - 1\frac{1}{2} = 2\frac{11}{16}$  in. Ans.

(550) A circle is drawn with a radius of 3 inches, which

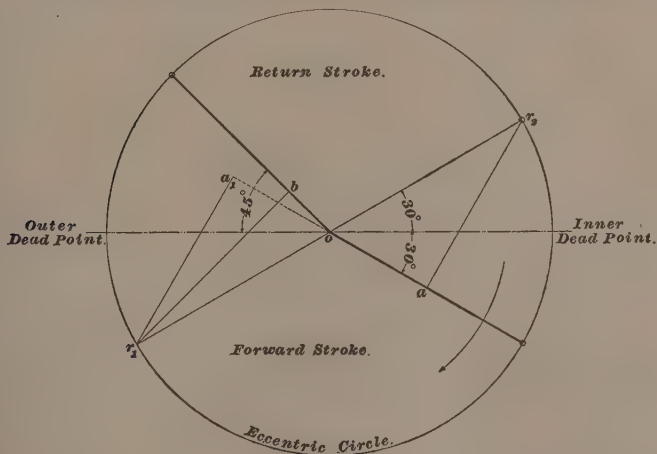


FIG. 20.

is one-half of the valve travel (Fig. 20). The line  $r_1 r_2$  is drawn, making an angle of  $30^\circ$  with the axis of the cylinder.



$m n$  at point  $a$ . Then, if  $m n$  represents the stroke,  $m a$  represents the part of the stroke completed by the piston when steam is cut off. That is,

$$m n : m a :: 24 : x.$$

By measurement  $x = 21.8$  in. Ans.

(c) Through point  $s$  draw a tangent to the lap circle parallel to the line  $m n$ . The distance between these lines is the lead, which, in this case, is  $\frac{3}{32}$  inch. Ans.

(552) Lay off the length  $m n$ , Fig. 22, equal to the valve travel, 5 inches in this case. Upon  $m n$  as a diameter, draw the semicircle  $m c n$ . From  $m$  lay off  $m a = \frac{5}{8} m n$ . Then, if the length  $m n$  represents the stroke,  $m a$  will represent the portion of stroke completed when the steam is

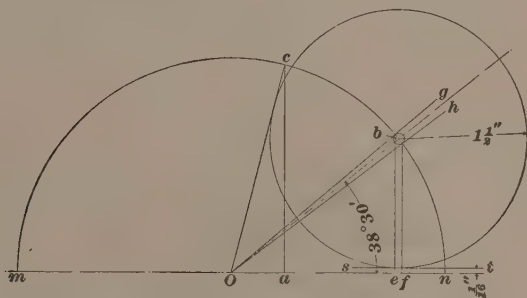


FIG. 22.

cut off, neglecting the angularity of the connecting-rod. Erect the perpendicular  $ac$ , and through the intersection  $c$  of the perpendicular with the semicircle, draw the radius  $Oc$ . Since the lead is  $\frac{1}{16}$  inch, draw the line  $st$  parallel to  $mn$  and  $\frac{1}{16}$  inch above it. Now find a center  $b$  upon the semicircle, about which the lap circle may be drawn so that it will touch lines  $Oc$  and  $st$ . The center  $b$  may be found

easily by trial. Draw the lap circle, and draw also the inside lap circle with a radius of  $\frac{1}{16}$  inch about  $b$  as a center.

Draw the two lines  $Og$  and  $Oh$  touching the inside lap circle, and from their intersection with the semicircle  $mcn$  drop perpendiculars cutting the diameter  $mn$  in points  $e$  and  $f$ , respectively. Then, if  $mn$  represents the stroke,  $me$  represents the portion of the stroke completed when compression begins, and  $mf$  represents the portion completed when the steam is released.

(a) The lap is the radius of the lap circle, which by measurement is found to be  $1\frac{1}{2}$  inches. Ans. The angle of advance is the angle  $bon$ , which is found to be  $38^{\circ} 30'$ . Ans.

(b) Neglecting the angularity of the connecting-rod, the point  $e$  represents the piston position at point of compression, and the point  $f$  represents the position at point of release. By measurement, it is found that compression occurs at  $\frac{7}{8}$  and release at  $\frac{9}{10}$  of the full stroke. Ans.

**(553)** See Arts. **932** and **933**.

**(554)** (a) Referring to Figs. 280 and 282, it is seen that the port opening is a maximum when the crank is at right angles to the angle of advance line, or when it is  $60^{\circ}$  from the dead point from which it is moving. The valve is in mid-position when the crank coincides with the angle of advance line, or when it is  $30^{\circ}$  from the dead point it is approaching.

**(555)** See Arts. **944** and **945**.

**(556)** See Art. **948**.

**(557)** See Arts. **951** and **952**.

**(558)** The diagram is shown in Fig. 23. The link in mid-position is shown by the center line  $efg$ , and in full position by the line  $e'g'$ . In changing from mid-gear to

full gear, the block is moved from  $f$  to  $e'$ , and the lead is increased by the distance  $f e'$ .

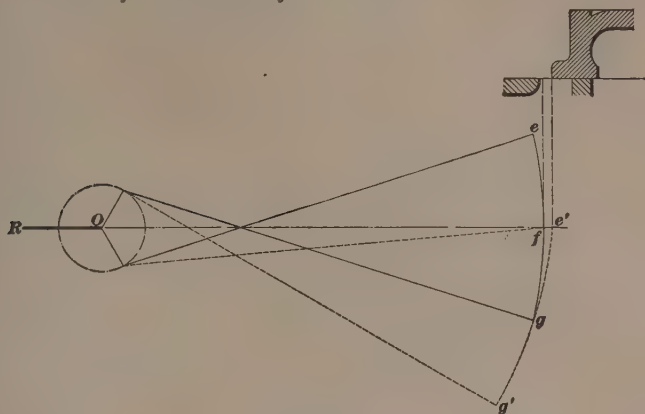


FIG. 23.

(559) See Art. 950. When the reversing rocker is used, the position is as shown in Fig. 24. If there is no

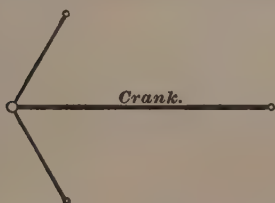


FIG. 24.

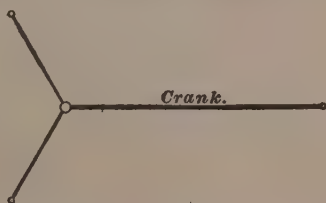


FIG. 25.

rocker, the position of the crank relative to the eccentric is as shown in Fig. 25.

(560) See Art. 954.

(561) See Art. 957.

(562) See Art. 959.

(563) The center line  $OC$ , Fig. 26, is first drawn. With  $O$  as a center, the eccentric circle  $FBF' B'$  is drawn with a diameter equal to the valve travel, in this case  $5\frac{3}{4}$  in.



FIG. 23.

Assuming the crank to be in position  $OR$ , the eccentrics  $OF$  and  $OB$  are located so that the angle  $ROF = ROB = 90^\circ + 22\frac{1}{2}^\circ = 112\frac{1}{2}^\circ$ . The angle  $22\frac{1}{2}^\circ$  may be found easily, since it is  $\frac{1}{8}$  of  $180^\circ$ . The point  $C$  is located 4 feet 4 inches from the center  $O$ . Since the link is 15 inches long, the lines  $hi$  and  $st$  are drawn parallel to  $OC$  above and below, respectively, at a distance of  $7\frac{1}{2}$  inches. With  $F$  as a center, and with a radius of 4 feet 4 inches, an arc is struck cutting line  $hi$  in point  $f$ . In a similar manner the points  $f'$ ,  $b$ , and  $b'$  are located, using points  $F'$ ,  $B$ , and  $B'$ , respectively, as centers. With the same radius, and with a center on the line  $OC$ , the arcs  $fb$  and  $f'b'$  are drawn; they represent the center lines of the link in its two extreme positions. With point  $C$  as a center, and a radius of 1 inch, the lap circle is drawn. The distances of the arcs  $fb$  and  $f'b'$  from the lap circle are the leads for the link in mid-gear. They are, respectively,  $\frac{3}{8}$  inch and  $\frac{9}{16}$  inch. When the link is in full gear, the lines  $c'g$  and  $c'g'$  represent its extreme positions. The lead in the right-hand position is  $\frac{1}{16}$  inch, and in the left-hand position it is  $\frac{1}{8}$  inch.

(564) See Arts. 964 to 968.

(565) See Art. 969. The diagrams showing arrange-

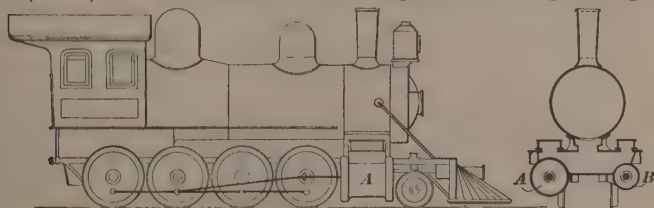


FIG. 27.

ment of cylinders are shown in Figs. 27, 28, and 29. In

each figure, *A* is the L. P. cylinder, *B* is the H. P. cylinder. In Fig. 28, *VV* are the valve chests.

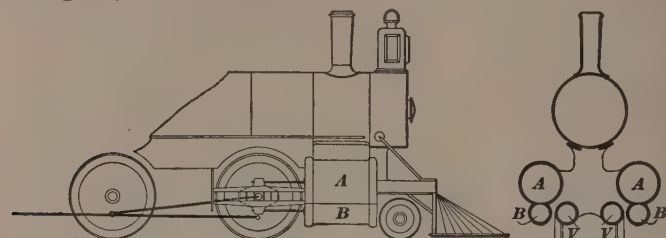


FIG. 28.

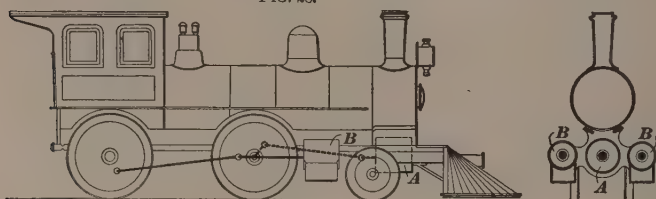


FIG. 29.

(566) See Arts. 971 and 972.

(567) (*a*) The tractive force is usually about  $\frac{1}{6}$  the weight on drivers.  $70,000 \times \frac{1}{6} = 14,000$  lb. Ans.

(*b*) Coefficient of friction =  $\frac{\text{tractive force}}{\text{weight on drivers}}$ .

(*c*) See Art. 977.

(568) Tractive force =  $1,100 \times 7 = 7,700$  lb. Weight on drivers =  $7,700 \div \frac{1}{6} = 46,200$  lb. Ans.

(569) Using the formula of rule 169, Art. 976,

$$d_L = \sqrt{\frac{TD}{pl}} = \sqrt{\frac{7,700 \times 45}{\frac{140}{6} \times 24}} = 22.7, \text{ say } 22\frac{3}{4} \text{ in. Ans.}$$

(570) See Art. 978.

(571) The volume of the L. P. cylinder may be assumed to be double the volume of the H. P. cylinder. Hence, according to rule 170, Art. 978,

$$d_H = \frac{d_L}{\sqrt{2}} = \frac{28.375}{\sqrt{2}} = 20\frac{1}{8} \text{ in. Ans.}$$



(572) Using rule 171, Art. 979,

$$d_1 = \sqrt{\frac{D W}{2.7 Pl}} = \sqrt{\frac{52 \times 36 \times 2,000}{2.7 \times 160 \times 22}} = \sqrt{394} = 19.85, \text{ say } 19\frac{7}{8} \text{ in. Ans.}$$

Using rule 172, Art. 979,

$$d_2 = \sqrt{\frac{d_1^2}{3}} = \sqrt{\frac{394}{3}} = 11\frac{7}{8} \text{ in. Ans.}$$

(573) See Arts. 997 to 1000.

(574) See Art. 1018.

(575) See Fig. 304. See Art. 1047.

(576) See Art. 1038.

(577) See description, Art. 1034. The arrangement of timbers is shown in Fig. 30.

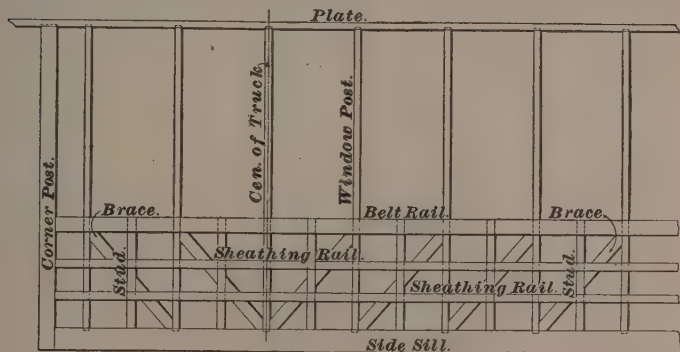


FIG. 30.

(578) See Art. 1010.

(579) See Arts. 1004 and 1005.

(580) See Arts. 982 to 1001.

(581) See Arts. 1067 and 1068.

(582) (a) See Art. 980.

(b) Since the volume of the two small cylinders combined is to equal the volume of the single L. P. cylinder, the volume of one of them should be  $\frac{1}{2}$  the volume of the 28 $\frac{3}{8}$ "

cylinder. The diameters vary directly as the square roots of the volumes, if the length of stroke remains the same. Let  $d$  = diameter of one of the small cylinders; then,

$$d : 28\frac{3}{8} :: 1 : \sqrt{2};$$

$$\text{or, } d = \frac{28\frac{3}{8}}{\sqrt{2}} = 20\frac{1}{16} \text{ in. Ans.}$$

(583) The freight train. See Art. 947.

(584) The relative position of these parts is shown in Fig. 31.

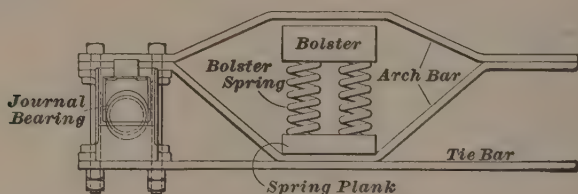


FIG. 31.

(585) See Arts. 1064 and 1065.

(586) See Art. 1056.

(587) (a) Using rule 169, Art. 976,

$$d_L = \sqrt{\frac{8,500 \times 64}{34 \times 24}} = 25\frac{1}{8} \text{ inches. Ans.}$$

Using rule 170, Art. 978, and assuming that the ratio of volume is 2,

$$d_u = \frac{25\frac{1}{8}}{\sqrt{2}} = 18\frac{1}{4} \text{ inches. Ans.}$$

(b) In this case, rules 171 and 172, Art. 979, are to be used.

$$d_L = \sqrt{\frac{64 \times 54,000}{2.7 \times 170 \times 24}} = 17\frac{3}{4} \text{ inches, nearly. Ans.}$$

$$d_u = \sqrt{\frac{(17\frac{3}{4})^2}{3}} = 10\frac{1}{2} \text{ inches, nearly. Ans.}$$

(588) See Art. 965.

(589) See Art. 935.

(590) See Art. 937.

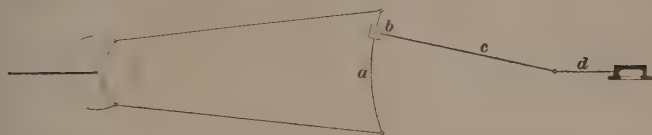


FIG. 32.

(591) A skeleton diagram of the Gooch link motion is shown in Fig. 32. The link *a* is curved towards the shaft as shown. The valve rod *d* is connected to the block *b* by the intermediate rod *c*. The link remains in a fixed position, and the block is movable.

(592) One dimension of the ports may be assumed and the other dimension calculated. If the proportions are not good a new assumption may be made. Assume first that the length of the port is 12 inches. Using rule 167, Art. 935,

$$w = \frac{.7854 \times 15^2 \times 550}{6,000 \times 12} = 1.35 \text{ in.}$$

This value is a little large. Assume  $13\frac{1}{2}$  inches for the length.

$$w = \frac{.7854 \times 15^2 \times 550}{6,000 \times 13.5} = 1.2 \text{ in.}$$

Either  $1\frac{3}{8}$  in. or  $1\frac{1}{4}$  in. might be used.



# DYNAMOS AND MOTORS.

(QUESTIONS 1079-1138.)

(1079) The end *b*; because in looking at that end the current circulates around the helix in an opposite direction to the hands of a watch. (Art. 2160.)

(1080) (a) Negative. (Art. 2138.)

(b) Negative. (Art. 2138.)

(c) Positive. (Art. 2138.)

(1081) By formula 311,  $C = \frac{E}{R}$ , where  $C$  is the current in amperes flowing in a closed circuit,  $E$  is the total generated E. M. F. in volts, and  $R$  is the total resistance in ohms of the circuit. In this example,  $E = 20$  volts and  $R = 30 + 80 = 110$  ohms; hence,  $C = \frac{E}{R} = \frac{20}{110} = .1818$  ampere. Ans.

(1082) Let  $A$  represent the first branch and  $B$  the second; then,  $r_1 = 16.2$  ohms,  $r_2 = 14.1$  ohms, and  $C = 6.37$  amperes.

The current  $c_1$ , in branch  $A$ , is found by using formula 315; substituting, gives  $c_1 = \frac{C r_2}{r_1 + r_2} = \frac{6.37 \times 14.1}{16.2 + 14.1} = 2.9643$  amperes. Ans.

The current  $c_2$ , in branch  $B$ , is found by using formula 316; substituting, gives

$$c_2 = \frac{C r_1}{r_1 + r_2} = \frac{6.37 \times 16.2}{16.2 + 14.1} = 3.4057 \text{ amperes. Ans.}$$

(1083) From formula 328,  $W = \text{H. P.} \times 746$ , where H. P. is the horsepower and  $W$  is the power in watts. In this example, H. P. = 2.33 horsepower; hence,  $W = \text{H. P.} \times 746 = 2.33 \times 746 = 1,738.18$  watts. Ans.

(1084) (a) From Art. **2195** and formula **311**,  $C = \frac{E'}{R'}$ , where  $C$  is the current in amperes,  $E'$  is the difference of potential in volts between two points, and  $R'$  is the resistance in ohms between them. In this example,  $E' = 58.4$  volts, and  $R' = 2.3$  ohms; hence,  $C = \frac{E'}{R'} = \frac{58.4}{2.3} = 25.3913$  amperes. Ans.

(b) From formula **326**,  $W = \frac{E^2}{R}$ , where  $W$  is the power in watts,  $E$  is the E. M. F., or difference of potential in volts, and  $R$  is the resistance in ohms. In this example,  $E = 58.4$  volts and  $R = 2.3$  ohms; hence,

$$W = \frac{E^2}{R} = \frac{58.4^2}{2.3} = \frac{3,410.56}{2.3} = 1,482.8521 \text{ watts. Ans.}$$

(c) By formula **327**,  $H. P. = \frac{W}{746}$ ; by formula **326**,  $W = \frac{E^2}{R}$ ; therefore (see Art. **2212**),  $H. P. = \frac{E^2}{746 R}$ , where H. P. is the horsepower,  $E$  the E. M. F., or difference of potential in volts, and  $R$  the resistance in ohms.

$$\text{Hence, } H. P. = \frac{58.4^2}{746 \times 2.3} = \frac{3,410.56}{1,715.8} = 1.9877 \text{ horsepower. Ans.}$$

(1085) Platinum, as it follows zinc in the list (Art. **2144**).

(1086) Towards the *east* (Art. **2157**).

(1087) By formula **313**,  $E = C R$ , where  $E$  is the total E. M. F. in volts developed in a closed circuit,  $C$  is the current in amperes flowing, and  $R$  is the total resistance in ohms of the circuit. In this example,  $C = .75$  ampere, and  $R = 17.2 + 8.2 + 11.3 = 36.7$  ohms; hence,  $E = C R = .75 \times 36.7 = 27.525$  volts, the total E. M. F. developed in the battery.

By derivation from formula **313**,  $E' = C R'$ , where  $E'$  is the difference of potential in volts between two points,  $C$  is

the current in amperes flowing, and  $R'$  is the resistance in ohms between the two points.

Between  $c$  and  $b$ ,  $R' = 8.2$  ohms, and  $C = .75$  ampere; hence,  $E' = CR' = .75 \times 8.2 = 6.15$  volts. Ans.

Between  $b$  and  $a$ ,  $R' = 11.3$  ohms, and  $C = .75$  ampere; hence,  $E' = CR' = .75 \times 11.3 = 8.475$  volts. Ans.

Between  $a$  and  $c$ , the difference of potential is the difference of potential between  $a$  and  $b$  plus that between  $b$  and  $c$ , which is  $8.475 + 6.15 = 14.625$  volts. Or, since the difference of potential between  $a$  and  $c$  is the available E. M. F. of the battery, when a current of .75 ampere is flowing, it can be calculated by using formula **314**,  $E' = E - Cr_i$ , where  $E'$  is the available E. M. F.,  $E$  is the total E. M. F. developed in the battery,  $C$  is the current flowing, and  $r_i$  is the internal resistance of the battery. In this case,  $E = 27.525$  volts,  $C = .75$  ampere, and  $r_i = 17.2$  ohms; hence,  $E' = E - Cr_i = 27.525 - (.75 \times 17.2) = 14.625$  volts. Ans.

**(1088)** The sectional area of a wire .2 in. in diameter is  $.7854 \times .2 \times .2 = .031416$  sq. in. or, nearly, .0314 sq. in.

Reduce the specific resistance in microhms to the resistance in ohms by dividing by 1,000,000 (Art. **2175**), which gives  $\frac{.5921}{1,000,000} = .0000005921$  ohm; or, in other words, the

resistance of a piece of silver one inch long, and whose sectional area is one square inch, is .0000005921 ohm. Next, from this resistance and length calculate the resistance of 1,000 feet of the silver with a sectional area of 1 sq. in. by

using formula **306**,  $r_2 = \frac{r_1 l_2}{l_1}$ , where  $r_1$  is the original resistance,  $r_2$  is the resistance after the length of the conductor is changed,  $l_1$  is the original length of the conductor, and  $l_2$  is the changed length. In this example,  $r_1 = .0000005921$  ohm,  $l_1 = 1$  inch, and  $l_2 = 1,000$  feet, or 12,000 inches

Hence, by substituting,  $r_2 = \frac{r_1 l_2}{l_1} = .0000005921 \times \frac{12,000}{1} = .0071052$  ohm; that is, the resistance of 1,000 feet of silver having a sectional area of 1 sq. in. is .0071052 ohm. From this result calculate the resistance of 1,000 feet of the

silver when its sectional area is .0314 sq. in., by using formula **307**,  $r_2 = \frac{r_1 a_1}{a_2}$ , where  $r_1$  is the original resistance,  $r_2$  is the resistance after the sectional area has been changed,  $a_1$  is the original area, and  $a_2$  is the changed sectional area. At this stage of the example,  $r_1 = .0071052$  ohm,  $a_1 = 1$  sq. in., and  $a_2 = .0314$  sq. in. Hence,

$$r_2 = \frac{.0071052 \times 1}{.0314} = .2262 \text{ ohm. Ans.}$$

(**1089**) By formula **313**,  $E = C R$ , where  $E$  is the total E. M. F. in volts developed in a closed circuit,  $C$  is the current in amperes flowing, and  $R$  is the total resistance in ohms of the circuit. In this example,  $C = .127$  ampere, and  $R = 36.2 + 21.7 = 57.9$  ohms. Hence, by substituting,  $E = C R = .127 \times 57.9 = 7.3533$  volts. Ans.

(**1090**) By formula **319**,  $Q = C t$ , where  $Q$  is the quantity of electricity in coulombs which passes through a circuit,  $C$  is the current in amperes flowing in that circuit, and  $t$  is the time in seconds during which the current flows. In this example,  $C = 8.32$  amperes, and  $t = 2.25 \times 60 \times 60 = 8,100$  seconds. Hence, by substituting,  $Q = C t = 8.32 \times 8,100 = 67,392$  coulombs. Ans.

(**1091**) By formula **324**,  $W = C E$ , where  $W$  is the power in watts,  $E$  is the E. M. F. in volts, and  $C$  is the current in amperes. In this example,  $E = 112.5$  volts, and  $C = 12.2$  amperes. Hence, by substituting,  $W = C E = 12.2 \times 112.5 = 1,372.5$  watts. Ans.

(**1092**) By formula **317**, the joint resistance of a derived circuit of two branches in parallel,  $R'' = \frac{r_1 r_2}{r_1 + r_2}$ . In this case,  $r_1 = 2.4$  and  $r_2 = 987.3$ ; then their joint resistance in parallel,  $R'' = \frac{2.4 \times 987.3}{2.4 + 987.3} = \frac{2,369.52}{989.7} = 2.3941$  ohms. Ans.

(**1093**) By formula **309**,  $r_2 = r_1 (1 + t k)$ , where  $r_1$  is the original resistance of a conductor,  $r_2$  is the resistance



after a rise in temperature,  $k$  is the temperature coefficient, and  $t$  is the rise of temperature in degrees F. In this example,  $r_1 = 43.2$  ohms,  $t = 85 - 60 = 25^\circ \text{ F.}$ , and  $k = .002155$ , from Table 60. Hence, by substituting,  $r_2 = r_1 (1 + t k) = 43.2 (1 + 25 \times .002155) = 43.2 \times 1.053875 = 45.5274$  ohms.

Ans.

(1094) By formula **318**, the joint resistance of three conductors in parallel  $R''' = \frac{r_1 r_2 r_3}{r_2 r_3 + r_1 r_3 + r_1 r_2}$ , where  $r_1$ ,  $r_2$ , and  $r_3$  are the separate resistances of the three conductors, respectively. In this example, let  $r_1 = 37$  ohms, the resistance of  $A$ ;  $r_2 = 45$  ohms, the resistance of  $B$ , and  $r_3 = 72$  ohms, the resistance of  $C$ . Substituting, gives

$$\frac{r_1 r_2 r_3}{r_2 r_3 + r_1 r_3 + r_1 r_2} = \frac{37 \times 45 \times 72}{45 \times 72 + 37 \times 72 + 37 \times 45} = \frac{119,880}{7,569} = 15.8383$$
 ohms, the joint resistance of the three conductors  $A$ ,  $B$ , and  $C$ , connected in parallel. Ans.

(1095) By formula **313**,  $E = C R$ , where  $E$  is the total E. M. F. in volts developed within a closed circuit,  $C$  is the current in amperes, and  $R$  is the total resistance in ohms of the circuit. In this example,  $C = 2.73$  amperes, and  $R = 49.3$  ohms; hence, by substituting,  $E = C R = 2.73 \times 49.3 = 134.589$  volts. Ans.

(1096) From Art. **2174**, the joint resistance of several conductors connected in series is equal to the sum of their separate resistances; hence, in this example, the joint resistance of the four conductors  $A$ ,  $B$ ,  $C$ , and  $D$ , in series, is  $3 + 19 + 72 + 111 = 205$  ohms. Ans.

(1097) (a) By formula **312**,  $R = \frac{E}{C}$ , where  $R$  is the total resistance in ohms of a closed circuit,  $E$  is the total E. M. F. in volts developed, and  $C$  is the current in amperes flowing in the circuit. In this example,  $E = 28.2$  volts, and  $C = 5.2$  amperes; hence,  $R = \frac{28.2}{5.2} = 5.423$  ohms. Ans.

(b) The total resistance of a closed circuit, Art. **2191**, is equal to the sum of the internal and external resistances

Since, in this example, the external resistance is 7 times the internal, and their sum is 5.423, let  $\frac{1}{8}$  of the total resistance represent the internal, and, therefore,  $\frac{7}{8}$  of the total resistance represents the external resistance. Hence,  $\frac{1}{8} \times 5.423 = .677875$  ohm, the internal resistance. Ans.

And  $\frac{7}{8} \times 5.423 = 4.745125$  ohms, the external resistance.

Ans.

(1098) We here use formula **321**,  $J = C^2 R t$ , where  $J$  is the work in joules,  $C$  is the current in amperes,  $R$  is the resistance in ohms, and  $t$  is the time in seconds. In this case  $C = 14.2$  amperes,  $R = 8$  ohms,  $t = 4,500$  seconds. Then, the work done  $= 14.2 \times 14.2 \times 8 \times 4,500 = 7,259,040$  joules. Ans.

(1099) By formula **310**,  $r_2 = \frac{r_1}{1 + t k}$ , where  $r_1$  is the original resistance of a conductor,  $r_2$  is the resistance after its temperature has fallen,  $t$  is the fall of temperature in degrees F., and  $k$  is the temperature coefficient. In this example,  $r_1 = 214$  ohms,  $t = 82 - 50 = 32^\circ \text{F.}$ , and  $k = .002094$ , from Table 60. Hence,

$$r_2 = \frac{r_1}{1 + t k} = \frac{214}{1 + 32 \times .002094} = \frac{214}{1.067008} = 200.5608 \text{ ohms.}$$

Ans.

(1100) From Art. **2206**, the separate resistance of any branch of a derived circuit is equal to the difference of potential between where all the branches divide and where they unite, divided by the current in that branch.

Hence, the separate resistance of branch  $A$  is  $\frac{11.6}{6.7} = 1.7313$  ohms. Ans.

The separate resistance of branch  $B$  is  $\frac{11.6}{4.9} = 2.3673$  ohms.

Ans.

(1101) By formula **312**,  $R = \frac{E}{C}$ , where  $R$  is the total resistance in ohms of a closed circuit,  $E$  is the total E. M. F. in volts developed in the circuit, and  $C$  is the current in amperes flowing in the circuit. In this example,  $E = 22.4$

volts, and  $C = .43$  ampere; hence,  $R = \frac{E}{C} = \frac{22.4}{.43} = 52.093$  ohms, the total resistance of the circuit. Since the total resistance of a closed circuit is equal to the sum of the external and internal resistances, the external resistance must be the difference between the total resistance and the internal resistance. Hence, the external resistance  $= 52.093 - 13.4 = 38.693$  ohms. Ans.

(1102) By transposition of terms in formula **319**,  $C = \frac{Q}{t}$ , where  $C$  is the current in amperes,  $Q$  is the quantity of electricity in coulombs, and  $t$  is the time in seconds. In this example,  $Q = 368,422$  coulombs, and  $t = 4.5 \times 60 \times 60 = 16,200$  seconds; hence,  $C = \frac{Q}{t} = \frac{368,422}{16,200} = 22.7421$  amperes. Ans.

(1103) By formula **321**,  $J = C^2 R t$ , where  $J$  is the work done in joules,  $C$  is the current in amperes,  $R$  is the resistance in ohms, and  $t$  is the time in seconds. In this example,  $C = 2.4$  amperes,  $R = 45$  ohms, and  $t = 3,000$  seconds. Then the electrical work done  $= 2.4 \times 2.4 \times 45 \times 3,000 = 777,600$  joules. By formula **323**, the mechanical work done  $= \text{F. P.} = .7373 J = .7373 \times 777,600 = 573,324.48$  foot-pounds. Ans.

(1104) By formula **327**,  $\text{H. P.} = \frac{W}{746}$ ; by formula **324**,  $W = CE$ ; therefore (see Art. **2212**),  $\text{H. P.} = \frac{E C}{746}$ , where H. P. is the horsepower,  $E$  is the E. M. F. in volts, and  $C$  is the current in amperes. In this example,  $E = 525$  volts, and  $C = 12.5$  amperes; hence,

$$\text{H. P.} = \frac{E C}{746} = \frac{525 \times 12.5}{746} = 8.7969 \text{ horsepower. Ans.}$$

(1105) (a) By formula **325**,  $W = C^2 R$ , where  $W$  is the power in watts,  $C$  is the current in amperes, and  $R$  is the resistance in ohms. In this example,  $C = 110$  amperes, and  $R = 4.2$  ohms; hence,  $W = C^2 R = 110^2 \times 4.2 = 50,820$  watts. Ans.

(b) By formula **327**,  $H. P. = \frac{W}{746}$ , where H. P. is the horsepower, and  $W$  is the power in watts. In this example,  $W = 50,820$  watts; hence,

$$H. P. = \frac{W}{746} = \frac{50,820}{746} = 68.1233 \text{ horsepower. Ans.}$$

(1106) The diagram, Fig. 97, shows the connections of the battery and galvanometer circuits to the circular type

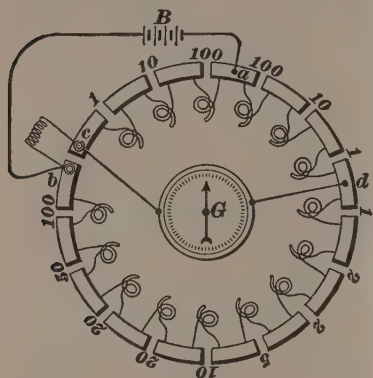


FIG. 97.

of resistance box for measuring unknown resistances by the Wheatstone's bridge method. The upper balance arm, Art. **2184**, of the bridge includes the resistance coils from  $c$  to  $a$ , the lower balance arm includes the coils from  $a$  to  $d$ , and the adjustable arm includes the coils from  $d$  to  $b$ . One pole of the battery  $B$  is connected to

the junction of the two balance arms; the other to the junction of the adjustable arm and the unknown resistance  $X$ . One terminal of the galvanometer  $G$  is connected to the junction of the lower balance arm and the adjustable arm; the other to the junction of the upper balance arm and the unknown resistance.

(1107) By formula **306**, the changed resistance for variation in length,  $r_2 = \frac{r_1 l_2}{l_1}$ , where  $r_1$  is the original resistance,  $l_1$  is the original length, and  $l_2$  is the changed length. In this case,  $r_1 = 1$  ohm,  $l_1 = 1,000$  feet, and  $l_2 = 2,000$  feet. Then, the changed resistance  $r_2 = \frac{1 \times 2,000}{1,000} = 2$  ohms. The next operation is to determine the resistance of the wire when its sectional area is changed. A round wire

.1" in diameter has a sectional area of  $.1^2 \times .7854 = .007854$  sq. in., and a square wire .1" on a side has a sectional area of  $.1 \times .1 = .01$  sq. in. By formula **307**,  $r_2 = \frac{r_1 a_1}{a_2}$ , where  $r_1$  is the original resistance of a conductor,  $r_2$  is the resistance after its sectional area is changed,  $a_1$  is the original sectional area, and  $a_2$  is the changed sectional area. At this stage of the example,  $r_1 = 2$  ohms,  $a_1 = .007854$  sq. in., and  $a_2 = .01$  sq. in. Hence,  $r_2 = \frac{r_1 a_1}{a_2} = \frac{2 \times .007854}{.01} = 1.5708$  ohms. Ans.

(1108) By formula **327**,  $H. P. = \frac{W}{746}$ , where H. P. is the horsepower, and  $W$  is the power in watts. In this example,  $W = 54,200$  watts; hence,  $H. P. = \frac{W}{746} = \frac{54,200}{746} = 72.6541$  horsepower. Ans.

(1109) The sectional area of a round column .04 in. in diameter is  $.04^2 \times .7854 = .00125664$  sq. in.; or .001257 sq. in., nearly.

Reduce the specific resistance in microhms to the resistance in ohms by dividing by 1,000,000, Art. **2175**, which gives  $\frac{37.15}{1,000,000} = .00003715$  ohm; or, in other words, the resistance of a quantity of mercury 1 in. long, and whose sectional area is 1 sq. in., is .00003715 ohm. Next, from this resistance and length, calculate the resistance of a column of mercury 72.3" high, with a sectional area of 1 sq. in. by using formula **306**,  $r_2 = \frac{r_1 l_2}{l_1}$ , where  $r_1$  is the original resistance of a conductor,  $r_2$  is the resistance after its length has been changed,  $l_1$  is its original length, and  $l_2$  is its changed length. In this example,  $r_1 = .00003715$  ohm,  $l_1 = 1$ ", and  $l_2 = 72.3$  inches. Hence,  $r_2 = \frac{r_1 l_2}{l_1} = \frac{.00003715 \times 72.3}{1} = .002685945$ , or .002686 ohm, nearly; or,

in other words, the resistance of a column of mercury 72.3" high, having a sectional area of 1 sq. in. is .002686 ohm. From this result calculate the resistance of the column when its sectional area is .001257 sq. in., by using formula **307**,  $r_2 = \frac{r_1 a_1}{a_2}$ , where  $r_1$  is the original resistance,  $r_2$  is the resistance after the sectional area has been changed,  $a_1$  is the original sectional area, and  $a_2$  is the changed sectional area. At this stage of the example,  $r_1 = .002686$  ohm,  $a_1 = 1$  sq. in., and  $a_2 = .001257$  sq. in. Hence,

$$r_2 = \frac{r_1 a_1}{a_2} = \frac{.002686 \times 1}{.001257} = 2.1368 \text{ ohms. Ans.}$$

(**1110**) By formula **311**,  $C = \frac{E}{R}$ , where  $C$  is the current in amperes flowing in a closed circuit,  $E$  is the total E. M. F. in volts generated, and  $R$  is the total resistance in ohms of the circuit. Since the total resistance of a closed circuit is the sum of the external and internal circuits,  $R = 33 + 30 = 63$  ohms, and  $E = 45$  volts; hence,  $C = \frac{E}{R} = \frac{45}{63} = .7143$  ampere. Ans.

(**1111**) In Fig. 28, question No. 1111, the reading of the voltmeter gives the total E. M. F. of the battery. Hence, after the connections are made, as shown in Fig. 29, question No. 1111, there is a closed circuit in which the total E. M. F. developed is 24.4 volts, and through which a current of .8 ampere is flowing. By formula **312**,  $R = \frac{E}{C}$ , where  $R$  is the total resistance in ohms of a closed circuit,  $E$  is the total E. M. F. in volts developed, and  $C$  is the current in amperes flowing. In this example,  $E = 24.4$  volts, and  $C = .8$  ampere; hence,  $R = \frac{E}{C} = \frac{24.4}{.8} = 30.5$  ohms, the total resistance of the circuit.

From the reading of the voltmeter, after the connections are made as shown in Fig. 29, it will be seen that when a current of .8 ampere flows through the external resistance

from  $b$  to  $a$ , through  $R$ , there is a drop or loss of potential of 18 volts. By formula **312**,  $R' = \frac{E'}{C}$ , where  $R'$  is the resistance of a conductor,  $E'$  is the drop or loss of potential in that conductor, and  $C$  is the current in amperes flowing through it. In this case,  $E' = 18$  volts, and  $C = .8$  ampere; hence,  $R' = \frac{E'}{C} = \frac{18}{.8} = 22.5$  ohms, the resistance of the external circuit from  $b$  to  $a$ , through the resistance  $R$ .  
Ans.

Since the total resistance of a closed circuit is the sum of the external and internal resistances, Art. **2191**, the internal resistance must be the difference between the total and external resistances. Hence,  $30.5 - 22.5 = 8$  ohms, the internal resistance of the battery  $B$ . Ans.

(**1112**) By formula **324**,  $W = C E$ , where  $W$  is the power in watts,  $E$  is the E. M. F., or difference of potential in volts, and  $C$  is the current in amperes. In this example,  $E = 510$  volts, and  $C = 24.3$  amperes; hence,  $W = 510 \times 24.3 = 12,393$  watts. Ans.

(**1113**) Referring to Art. **2187**, the total E. M. F. developed by connecting several cells in series is equal to the E. M. F. of one cell multiplied by the number of cells; hence, the E. M. F. of one of the groups of 6 cells is  $6 \times 1.5 = 9$  volts. In the same article it is stated that connecting cells in multiple, or parallel, does not change the E. M. F. between the main conductors. In this case each group of six cells can be considered as one large cell developing an E. M. F. of 9 volts, and, consequently, the E. M. F. of the four groups connected in multiple, or parallel, is 9 volts, which would be the E. M. F. indicated by a voltmeter, connected to the main conductors  $C$  and  $C'$ , as shown in Fig. 30, question No. 1113.  
Ans.

(**1114**) By formula **327**,  $H. P. = \frac{W}{746}$ ; by formula **324**,  $W = C E$ ; therefore (see Art. **2212**),  $H. P. = \frac{E C}{746}$ ,



where H. P. is the horsepower,  $E$  is the E. M. F. in volts, and  $C$  is the current in amperes. In this example,  $E = 250$  volts, and  $C = 65.7$  amperes; hence,  $H. P. = \frac{EC}{746} = \frac{250 \times 65.7}{746} = \frac{16,425}{746} = 22.0174$  horsepower. Ans.

(1115) In Art. 2157 it is stated that when a compass is placed under a conductor in which an electric current is flowing from the south to the north, the north pole of the compass needle tends to point towards the west, and if the direction of the current in the conductor is reversed, the north pole will point towards the east. Since, in this example, the north pole of the needle tends to point towards the east, the current must be flowing *from* the north *to* the south.

(1116) End  $a$ ; since (Art. 2160), in looking at the face of the end  $a$ , the current circulates around the core in the same direction as the movement of the hands of a watch.

(1117) Attract one another; since (Art. 2138), a positive charge is developed upon the ivory when rubbed with silk, and a negative charge upon sealing-wax when rubbed with fur; and from Art. 2137, electrified bodies with dissimilar charges are mutually attractive.

(1118) The exposed end of the iron; since, from Art. 2144, the iron forms the positive element of the cell, and, from Art. 2143, the pole, or electrode, attached to the exposed end of a voltaic element is always of opposite sign to the element itself.

(1119) From Art. 2152, iron and its alloys, nickel, cobalt, manganese, oxygen, cerium, and chromium.

(1120) Towards the south pole, since, from Art. 2151, unlike poles attract one another.

(1121) Towards the north pole, since, from Art. 2151, unlike poles attract one another.

(1122) *From* the north *to* the south, since, from Art. 2157, the north pole of a compass needle tends to point to-



wards the east when the compass is placed over a conductor in which the current is flowing from the south to the north; and, by reversing the direction of the current in the conductor, the north pole of the needle tends to point towards the west, and the south pole towards the east.

(1123) The current should enter the wire at end *b*; since (Art. 2160), in looking at the face of the south pole of the magnet, the current should circulate around the core in the direction of motion of the hands of a watch.

(1124) By formula 306,  $r_2 = \frac{r_1 l_2}{l_1}$ , where  $r_1$  is the original resistance of a conductor,  $r_2$  is the resistance after its length has been changed,  $l_1$  is the original length, and  $l_2$  is its changed length. In this example,  $r_1 = 100.8$  ohms,  $l_1 = (112 \times 12) + 6 = 1,350$  inches,  $l_2 = 11.7$  inches. Hence,

$$r_2 = \frac{r_1 l_2}{l_1} = \frac{100.8 \times 11.7}{1,350} = .8736 \text{ ohm. Ans.}$$

(1125) By formula 308,  $r_2 = \frac{r_1 D^2}{d^2}$ , where  $r_1$  is the original resistance of a round conductor,  $r_2$  is the resistance after its diameter has been changed,  $D$  is its original diameter, and  $d$  is its changed diameter. In this example,  $r_1 = 86.5$  ohms,  $D = .1$  inch, and  $d = .02$  inch; hence,  $r_2 = \frac{r_1 D^2}{d^2} = \frac{86.5 \times .1^2}{.02^2} = \frac{86.5 \times .01}{.0004} = 2,162.5$  ohms. Ans.

(1126) By formula 309,  $r_2 = r_1 (1 + t k)$ , where  $r_1$  is the original resistance of a conductor,  $r_2$  is the resistance after its temperature has risen,  $k$  is the temperature coefficient, and  $t$  is the number of degrees rise Fahrenheit. In this example,  $r_1 = 91.8$  ohms,  $t = 72 - 45 = 27$  degrees, and  $k = .000244$ , from Table 60. Hence,  $r_2 = r_1 (1 + t k) = 91.8 (1 + 27 \times .000244) = 91.8 \times 1.006588 = 92.4048$  ohms. Ans.

(1127) By formula 310,  $r_2 = \frac{r_1}{1 + t k}$ , where  $r_1$  is the original resistance of a conductor,  $r_2$  is the resistance after its temperature has fallen,  $t$  is the number of degrees

fall Fahrenheit, and  $k$  is the temperature coefficient of the material. In this example,  $r_1 = .144$  ohm,  $t = 87 - 41 = 46$  degrees Fahrenheit, and  $k = .002155$ , from Table 60. Hence,

$$r_2 = \frac{r_1}{1 + t k} = \frac{.144}{1 + 46 \times .002155} = \frac{.144}{1.09913} = .131 \text{ ohm.}$$

Ans.

(1128) First reduce the specific resistance in microhms to the resistance in ohms by dividing by 1,000,000, Art.

**2175**, which gives  $\frac{3.565}{1,000,000} = .000003565$  ohm; or, in

other words, the resistance of a block of platinum one inch long, and whose sectional area is one square inch, is .000003565 ohm. Next, from this resistance and length, calculate the resistance of 126 feet of platinum with a

sectional area of 1 sq. in., by using formula **306**,  $r_2 = \frac{r_1 l_2}{l_1}$ ,

where  $r_1$  is the original resistance of a conductor,  $r_2$  is the resistance after its length has been changed,  $l_1$  is the original length of the conductor, and  $l_2$  is its changed length. In this example,  $r_1 = .000003565$  ohm,  $l_1 = 1$  inch, and  $l_2 = 126 \times 12 = 1,512$  inches. Hence,

$$r_2 = \frac{r_1 l_2}{l_1} = \frac{.000003565 \times 1,512}{1} = .005390280 \text{ ohm;}$$

that is, the resistance of 126 feet of platinum having a sectional area of 1 sq. in. is .00539 ohm, nearly. From this result calculate the resistance of 126 feet of platinum when its sectional area =  $.1^2 \times .7854 = .007854$  sq. in., by using formula **307**,

$r_2 = \frac{r_1 a_1}{a_2}$ , where  $r_1$  is the original resistance of a conductor,

$r_2$  is the resistance after its sectional area is changed,  $a_1$  is its original sectional area, and  $a_2$  is its changed sectional area. At this stage of the example,  $r_1 = .00539$  ohm,  $a_1 =$

1 sq. in.,  $a_2 = .007854$  sq. in. Hence,  $r_2 = \frac{.00539 \times 1}{.007854} = .6863$  ohm. Ans.

(1129) From Art. **2184**, the fundamental equation of the Wheatstone's bridge is  $X = \frac{M}{N} \times P$ , where  $X$  is the

unknown resistance,  $M$  is the resistance of the upper balance arm,  $N$  is the resistance of the lower balance arm, and  $P$  is the resistance of the adjustable arm. It will be seen from the connections of the battery and galvanometer circuits in the diagram that the coils lying between  $c$  and  $a$  form the upper balance arm of the bridge, and, hence, in this example,  $M = 1$  ohm; the coils between  $a$  and  $d$  form the lower balance arm, and, hence,  $N = 100$  ohms; the coils between  $d$  and  $b$  form the adjustable arm, and, hence,  $P = 500 + 200 + 20 + 2 + 1 = 723$  ohms. Substituting these values in the fundamental equation, gives

$$X = \frac{M}{N} \times P = \frac{1}{100} \times 723 = 7.23 \text{ ohms. Ans.}$$

(1130) By formula **311**,  $C = \frac{E}{R}$ , where  $C$  is the current in amperes flowing in a closed circuit,  $E$  is the total E. M. F. in volts developed in the circuit, and  $R$  is the total resistance in ohms of the circuit. In this example,  $E = 36$  volts, and  $R = 24 + 18 = 42$  ohms; since, Art. **2191**, the total resistance of a closed circuit is the sum of the internal and external resistances. Hence,  $C = \frac{E}{R} = \frac{36}{42} = .8571$  ampere. Ans.

(1131) By formula **312**,  $R = \frac{E}{C}$ , where  $R$  is the total resistance in ohms of a closed circuit,  $E$  is the total E. M. F. in volts developed in the circuit, and  $C$  is the current in amperes flowing through the circuit. In this example,  $E = 12.6$  volts, and  $C = 2.7$  amperes; hence,  $R = \frac{E}{C} = \frac{12.6}{2.7} = 4.6667$  ohms. Ans.

(1132) By formula **313**,  $E = CR$ , where  $E$  is the total E. M. F. in volts developed in a closed circuit,  $C$  is the current in amperes flowing through the circuit, and  $R$  is the total resistance of the circuit. In this example,  $C = .8$  ampere, and  $R = 31.5 + 11 = 42.5$  ohms, since, Art.

**2191**, the total resistance of a closed circuit is the sum of the internal and external resistances. Hence,  $E = CR = .8 \times 42.5 = 34$  volts. Ans.

(**1133**) By formula **313**,  $E' = CR'$ , where  $E'$  is the difference of potential in volts between two points in a circuit,  $C$  is the current in amperes flowing through the circuit, and  $R'$  is the resistance of the circuit between the two points. In this example,  $C = .12$  ampere, and  $R' = 204$  ohms; hence,  $E' = CR' = .12 \times 204 = 24.48$  volts. Ans.

(**1134**) (a) By formula **312**,  $R' = \frac{E'}{C}$ , where  $R'$  is the total resistance in ohms between two points in a circuit,  $E'$  is the drop or loss of potential in volts between the two points, and  $C$  is the current in amperes flowing in the circuit. In this example, the two conductors leading to and from the receptive device can be considered as in series, forming one single conductor 1,200 feet in length, in which the drop or loss of potential is 10% of 250 volts, or  $.10 \times 250 = 25$  volts; that is,  $E' = 25$  volts. Since,  $C = 80$  amperes, then,  $R' = \frac{E'}{C} = \frac{25}{80} = .3125$  ohm; or, in other words, the sum of the resistances of two conductors which transmit a current of 80 amperes to and from the receptive device with a loss of 25 volts is .3125 ohm. Ans.

(b) The resistance per foot of any conductor is found by dividing its total resistance by its length in feet. Assume the two conductors leading to and from the receptive device to be one single conductor 1,200 feet in length, and offering a resistance of .3125 ohm; hence, its resistance per foot is

$$\frac{.3125}{1,200} = .00026 \text{ ohm. Ans.}$$

(**1135**) By formula **311**,  $C = \frac{E}{R}$ , where  $C$  is the current in amperes flowing in a closed circuit,  $E$  is the total E. M. F. in volts developed in the circuit, and  $R$  is the total resistance in ohms of the circuit. In this example,  $E = 24$  volts, and  $R = 8.1 + 15.9 = 24$  ohms, since, Art.

**2191**, the total resistance of a closed circuit is the sum of the internal and external resistances. Hence,

$$C = \frac{E}{R} = \frac{24}{24} = 1 \text{ ampere.}$$

By formula **314**,  $E' = E - C r_i$ , where  $E'$  is the available, or external, E. M. F. in volts of a battery or other electric source in a closed circuit,  $E$  is the total E. M. F. in volts developed in the source,  $C$  is the current in amperes flowing through the circuit, and  $r_i$  is the internal resistance of the battery or electric source. In this example,  $E = 24$  volts,  $C = 1$  ampere, and  $r_i = 8.1$  ohms. Hence,  $E' = E - C r_i = 24 - (8.1 \times 1) = 15.9$  volts. Ans.

**(1136)** Let  $A$  represent the first branch, and  $B$  the second; then  $r_1 = 1.2$  ohms,  $r_2 = 2.2$  ohms, and  $C = 45$  amperes.

The current  $c_1$  in branch  $A$  will then be found by substituting these values in formula **315**, which gives

$$c_1 = \frac{C r_2}{r_1 + r_2} = \frac{45 \times 2.2}{1.2 + 2.2} = \frac{99}{3.4} = 29.1176 \text{ amperes. Ans.}$$

Since the sum of the currents in the two branches is 45 amperes, the current in branch  $B$  is, therefore, the difference between 45 amperes and the current in branch  $A$ , or  $45 - 29.1176 = 15.8824$  amperes. Ans.

**(1137)** By formula **317**, the joint resistance of two conductors connected in parallel is equal to the product of

their separate resistances divided by their sum, or  $\frac{r_1 r_2}{r_1 + r_2}$ ,

where  $r_1$  and  $r_2$  are the separate resistances of the two branches. In this example,  $r_1 = 45$  ohms, and  $r_2 = 63$  ohms.

Hence,  $\frac{45 \times 63}{45 + 63} = 26.25$  ohms, the joint resistance of the two conductors connected in parallel.

**(1138)** From Art. **2203**, the joint resistance of three conductors connected in parallel is given by formula **318**,

$$R''' = \frac{r_1 r_2 r_3}{r_1 r_2 + r_1 r_3 + r_2 r_3}, \text{ where } r_1, r_2, \text{ and } r_3 \text{ are the separate}$$

resistances of the three conductors, respectively. In this example, let  $r_1 = 414$  ohms,  $r_2 = 810$  ohms, and  $r_3 = 1,206$  ohms. Then, the joint resistance of the three conductors  $A$ ,  $B$ , and  $C$  when connected in parallel is

$$\frac{r_1 r_2 r_3}{r_2 r_3 + r_1 r_3 + r_1 r_2} = \frac{414 \times 810 \times 1,206}{810 \times 1,206 + 414 \times 1,206 + 414 \times 810} =$$

$$\frac{404,420,040}{976,860 + 499,284 + 335,340} = \frac{404,420,040}{1,811,484} = 223.2534 \text{ ohms.}$$

Ans.

# DYNAMOS AND MOTORS.

(QUESTIONS 1139-1188.)

(1139) By formula **329**,  $E = \frac{2 N S n}{10^8}$ . In this example,  $N = 6,250,000$  lines of force,  $S = 100$  outside, or face, wires in series, for if 200 turns were wound around the core, there would be 200 outside, or face, wires, and, from Art. **2236**, one-half would be connected in series, and  $n = \frac{1,200}{60}$  revolutions per second. Substituting these values in above formula gives  $E = \frac{2 N S n}{10^8} = \frac{2 \times 6,250,000 \times 100 \times 1,200}{100,000,000 \times 60} = 250$  volts. Ans.

(1140) From Art. **2249**, it will be seen that the current in the shunt field of a dynamo is equal to the difference of potential between the brushes divided by the resistance of the shunt field circuit, or  $C_s = \frac{E}{R_s}$ . In this example,  $E = 220$  volts, and  $R_s = 440$  ohms; hence,  $C_s = \frac{E}{R_s} = \frac{220}{440} = .5$  ampere. Ans.

(1141) See Arts. **2226** and **2227**.

(1142) In Art. **2214**, it is stated that a current will be induced in a closed coil or circuit when there is a change in the number of lines of force passing through that coil or circuit. In this case, as the magnetic field is uniform, there is no change in the number of lines of force passing through the coil  $C$  when it is moved from its original position to the position  $C'$ , as shown by the dotted outlines; and, hence, no current will flow around the ring.

(1143) Use formula **333**. In order to determine the result in watts, it is necessary to reduce all quantities to the same units; hence, the first operation is to reduce the input from horsepower to watts. From Art. **2212**, one horsepower is equivalent to 746 watts; therefore, the input =  $18 \times 746 = 13,428$  watts. And, by formula **333**, the output

$$O = \frac{13,428 \times 88}{100} = 11,816.64 \text{ watts. Ans.}$$

(1144) In this example, it is first necessary to determine the input in watts. By formula **332**, the input  $I = \frac{100 \times 17,500}{87.5} = 20,000$  watts. As in Art. **2277**, it will be seen that the watts lost in field coils are equal to the input in watts multiplied by the per cent. loss and divided by 100. Hence, the loss =  $\frac{20,000 \times 2.6}{100} = 520$  watts. Ans.

(1145) In Art. **2280**,  $C_s = \frac{E_e}{r_s}$ . In this example,  $C_s = \frac{110}{55} = 2$  amperes. By formula **324**, the watts lost in the shunt circuit are equal to the difference of potential between the terminals of that circuit multiplied by the current in amperes flowing through the circuit; or,  $W = E \times C$ . Substituting, we have  $W = 110 \times 2 = 220$  watts. Ans.

(1146) See Art. **2227** and Art. **2232**.

(1147) From Ohm's law, the resistance of the field circuit is equal to the difference of potential between the brushes divided by the current in the field circuit. Let  $E_e$  be the difference of potential between the brushes of the dynamo,  $C_1$  be the strength of current when the resistance is all in circuit, and  $C_s$  be the strength of current when the resistance is cut out, or short-circuited. If  $r_1$  represents the resistance of the field circuit, including that of the rheostat, then  $r_1 = \frac{E_e}{C_1} = \frac{360}{1.5} = 240$  ohms; and if  $r_s$  represents the resistance of the field circuit when the resistance of the rheostat



has been cut out, or short-circuited, then  $r_2 = \frac{E_e}{C_2} = \frac{360}{1.8} = 200$  ohms. Hence, the amount of resistance which was cut out, or short-circuited, in the rheostat is the difference between these two resistances, or  $240 - 200 = 40$  ohms. Ans.

(1148) Use formula **332**. In this example, the input  $= \frac{100 \times 65,000}{90.5} = 71,823.2044$  watts. Since one horsepower equals 746 watts, then 71,823.2044 watts equal  $\frac{71,823.2044}{746} = 96.2778$  horsepower. Ans.

(1149) If the current circulates in the direction indicated by the arrow-heads, *neither* pole-piece will be a north pole; for, by applying the rule given in Art. **2160**, it will be seen that the north pole of one field coil is opposite the south pole of the other, and the lines of force circulate around the magnets without passing through the armature. If the winding of the right-hand coil were reversed, its top would be a north pole, and the top of the left-hand coil being also north, the pole-piece *P* would become a north consequent pole.

(1150) See Arts. **2232** and **2234**.

(1151) In this example, it is first necessary to change the input from horsepower to watts. Since one horsepower is equivalent to 746 watts, then 10 horsepower are equivalent to  $10 \times 746 = 7,460$  watts. Then, by formula **330**, the efficiency  $E = \frac{6,341 \times 100}{7,460} = 85$  per cent. Ans.

(1152) From *b* to *a* through the conductor; for, by applying the thumb-and-finger rule given in Art. **2221**, as indicated, it will be seen that the middle finger is pointing towards *a* from *b*.

(1153) In this example, it is first necessary to find the input in watts. In this example, the output = 11,900 watts, and the per cent. efficiency = 85. Then, by formula **332**, the input  $= \frac{100 \times 11,900}{85} = 14,000$  watts input. As in Art.

**2277**, the watts lost are found by multiplying the input by the per cent. loss and dividing by 100. Hence,  

$$\frac{14,000 \times 1.8}{100} = 252 \text{ watts lost in core by eddy currents and hysteresis. Ans.}$$

**(1154)** (a) See Art. **2241**. (b) See Art. **2238**.

**(1155)** According to Art. **2283** and formula **325**,  $W_i = C^2 r_i$ . In this example,  $C = 120$  amperes, and  $r_i = .040$  ohm; hence,  $W_i = 120^2 \times .040 = 576$  watts. Ans.

**(1156)** From example 1155, the normal output from the dynamo is 120 amperes at 125 volts, or  $120 \times 125 = 15,000$  watts. The next step is to determine the input at this output when the efficiency is 75%. By formula **332**, the input in this case is  $\frac{100 \times 15,000}{75} = 20,000$  watts. From example 1155, there are 576 watts lost in the armature due to its resistance, and, from Art. **2285**, the loss in the armature due to its resistance is  $\frac{576 \times 100}{20,000} = 2.88\%$ . Ans.

**(1157)** See Arts. **2289** and **2290**.

**(1158)** Under Field Losses, in Art. **2279**, the watts lost in the series coils is found by using formula **325**, where  $W = C^2 R$ . In this example,  $C = 40$  amperes, and  $R = .04$  ohm; hence,  $W = 40^2 \times .04 = 40 \times 40 \times .04 = 64$  watts, which represents the loss in the series coils. The watts lost in the shunt coil is given by formula **326**, where  $W = \frac{E^2}{R}$ . In this case,  $E = 550$  volts, and  $R = 550$  ohms; hence,  $W = \frac{E^2}{R} = \frac{550 \times 550}{550} = 550$  watts, which is the loss in the shunt field. The total loss in the fields of a compound dynamo is equal to the sum of the losses in the series and shunt coils. Hence, the total loss in this case is  $64 + 550 = 614$  watts. Ans.

**(1159)**  $P'$  is the south consequent pole of the field, since, from the rule in Art. **2160**, in looking through the coils  $c$  and  $d$  from a position near  $P'$ , the current is circula-

ting around the field cores in the same direction as the movements of the hands of a watch; while, on the contrary, in looking through the coils  $a$  and  $b$  from a position near  $P$ , the current is circulating around the upper field cores in a direction opposite to the movements of the hands of a watch.

(1160) See Art. 2242.

(1161) From Art. 2277, the total loss in a dynamo is the sum of the separate losses; hence, in this example, the total loss in watts is  $356 + 178 + 263 + 423 + 50 = 1,270$  watts. From Art. 2272, the input to the dynamo in this case is  $15,000 + 1,270 = 16,270$  watts. By formula 330 the efficiency  $E = \frac{15,000 \times 100}{16,270} = 92.1942\%$  at this output. Ans.

(1162) From example 1161, the loss in mechanical friction is 356 watts, and the input is 16,270 watts; hence (see Art. 2285), the per cent. loss is  $\frac{356 \times 100}{16,270} = 2.1881\%$ . Ans. (a).

From example 1161, the loss in the core by eddy currents and hysteresis is 178 watts, and the input is 16,270 watts; hence (see Art. 2285), the per cent. loss is  $\frac{178 \times 100}{16,270} = 1.094\%$ . Ans. (b).

From example 1161, the loss in the field coils is 263 watts, and the input is 16,270 watts; hence, the per cent. loss is  $\frac{263 \times 100}{16,270} = 1.6165\%$ . Ans. (c).

From example 1161, the loss in the armature ( $C^2 r$ ) = 423 watts, and the input is 16,270 watts; hence, the per cent. loss is  $\frac{423 \times 100}{16,270} = 2.5999\%$ . Ans. (d).

From example 1161, the sum of the separate losses is 1,270 watts, and this is the difference between the input and the output; the input is 16,270 watts; then, by formula 331, the total per cent. loss  $L = \frac{100 \times 1,270}{16,270} = 7.8058\%$ . Ans. (e).

(1163) From Art. 2235, it will be seen that the electromotive force generated in an armature is proportional to the speed, other conditions and quantities remaining unchanged. Hence, in this example, if  $E$  represents the electromotive force which is generated when the armature is driven at 1,400 revolutions per minute, then, by proportion,  $440 : E :: 1,200 : 1,400$ , or  $E \times 1,200 = 440 \times 1,400$ ; therefore,  $E = \frac{440 \times 1,400}{1,200} = 513\frac{1}{3}$  volts. Ans.

(1164) See Art. 2286, and those following.

(1165) In Art. 2219, under Mutual Induction, it is stated that when the current in the primary circuit tends to increase in strength, the induced current in the secondary coil will tend to circulate around the core which forms the magnetic circuit of both coils, in the opposite direction to that of the current in the primary circuit. In this case the current in the primary circuit flows from the positive terminal  $n$  of the battery when the circuit is closed, around the coil to the negative terminal  $m$ ; or, in other words, the current circulates around the core in an opposite direction to the movements of the hands of a watch, as viewed by a person looking through the coil from a position near  $C$ . Consequently, the momentary current induced in the secondary coil  $S$  would tend to circulate around the core in the reverse direction, that is, in the same direction as the movements of the hands of a watch. The direction of the current in the secondary circuit would, therefore, be from the terminal  $x$  through the coil to  $y$ , and then through the resistance  $R$  to  $x$  again.

(1166) In Art. 2219, under Mutual Induction, it is stated that when the strength of the current in the primary circuit suddenly decreases, the momentary current induced in the secondary coil will circulate around the core which forms the magnetic circuit of both coils in the same direction to that of the current in the primary coil. In this case, when the strength of the current in the primary circuit suddenly decreases, it continues to flow in the same direction

as in example 1165; that is, from the terminal  $n$  through the primary coil  $P$  to  $m$ , and completing the circuit to  $n$  through the battery  $B$ . Consequently, the current in the secondary coil  $S$  circulates around the core in the same direction; that is, from  $y$  through the secondary coil  $S$  to  $x$ , completing the circuit to  $y$  again through the resistance  $R$ .

(1167) See Arts. **2291** and **2292**.

(1168) Yes; because (Art. **2214**) a change takes place in number of lines which pass through the coil. From the rule given in Art. **2220**, it will be seen that the current will circulate around the ring in the same direction as the movements of the hands of a watch; for the effect of the motion is to diminish the number of lines of force which pass through the coil, and the observer is looking along the magnetic field in the direction of the lines of force.

(1169) See Art. **2255**.

(1170) From Art. **2224**, it will be seen that the *rate of cutting* lines of force is found by dividing the number cut by the time required to cut them; hence, in this case, the rate of cutting is  $\frac{8,000,000}{.25} = 32,000,000$  lines of force per second.

(1171) Because the solid iron core would act as a large conductor cutting lines of force at an angle, and thereby producing *local*, or *eddy*, currents in the core, heating it badly, and uselessly dissipating a large amount of energy. (Art. **2229**.)

(1172) By formula **329**,  $E = \frac{2NSn}{10^8}$ . In this example, if 150 complete turns of wire are wound upon the drum core, there will be 300 outside, or face, wires, and one-half of these will be connected in series, as explained in Art. **2234**, then,  $S = 150$  outside wires connected in series,  $N = 2,500,000$  lines of force, and  $n = \frac{1,020}{60}$ . Hence,  

$$E = \frac{2NSn}{10^8} = \frac{2 \times 2,500,000 \times 150 \times 1,020}{100,000,000 \times 60} = 127.5 \text{ volts. Ans.}$$

(1173) From Art. **2235**, it will be seen that the electromotive force generated in an armature is proportional to the number of lines of force passing through the core. Let  $E$  represent the electromotive force which is generated when 1,250,000 lines of force are passing through the core; then, by proportion,  $200 : E :: 750,000 : 1,250,000$ , or  $E \times 750,000 = 200 \times 1,250,000$ ; therefore,  $E = \frac{200 \times 1,250,000}{750,000} = 333\frac{1}{3}$  volts. Ans.

(1174) (a) See Art. **2278**. (b) See Art. **2283**. (c) See Art. **2279**.

(1175) Towards the side  $a$ ; for by applying the thumb-and-finger rule given in Art. **2239**, and making the fore-finger point in the direction of the lines of force and the middle finger in the direction of the current, the thumb will point towards the side  $a$ .

(1176) Use the formula given under Field Losses in Art. **2280**,  $C_s = \frac{E_e}{r_s}$ , which is a modification of formula **311**. In this example,  $E_e = 525$  volts, and  $r_s = 650$  ohms; hence,  $C_s = \frac{E_e}{r_s} = \frac{525}{650} = .8076$  ampere. Ans.

(1177) The increase in voltage from no load to full load is  $124.2 - 115 = 9.2$  volts, which is  $\frac{9.2 \times 100}{115} = 8\%$  of the normal voltage. Therefore, the over-compounding is 8%. Ans.

(1178) See Art. **2233**.

(1179) First change the input from horsepower to watts. Since one horsepower is equivalent to 746 watts, 44 horsepower are equivalent to  $44 \times 746 = 32,824$  watts. By formula **330**, the efficiency

$$E = \frac{100 \times 29,820}{32,824} = 90.8481\%. \quad \text{Ans.}$$

(1180) In this example, the input  $I = 20,000$  watts, and the output  $O = 17,500$  watts. Then, by formula **331**, the per cent. loss  $L = \frac{100 \times (20,000 - 17,500)}{20,000} = 12.5\%$ . Ans.

(1181) In this example, the output is 12,500 watts, and the efficiency is 92.5%. Consequently, by formula **332**, the input  $I = \frac{100 \times 12,500}{92.5} = 13,513.5135$  watts. Reducing this input from watts to horsepower, gives

$$\frac{13,513.5135}{746} = 18.1146 \text{ horsepower. Ans.}$$

(1182) See Art. **2286**.

(1183) In this example, it is first necessary to change the input from horsepower to watts. Since one horsepower is equivalent to 746 watts, fifty-five horsepower are equivalent to  $55 \times 746 = 41,030$  watts. The output of the dynamo, by formula **333**,  $= \frac{41,030 \times 88.5}{100} = 36,311.55$  watts. Ans.

(1184) In the same manner as shown in Art. **2277**, it will be seen that the loss in watts in the field coils is equal to the input multiplied by the per cent. loss and divided by 100. In this example, it is first necessary to change the input from horsepower to watts. Since one horsepower is equivalent to 746 watts, forty-five horsepower are equivalent to  $45 \times 746 = 33,570$  watts. Consequently, the loss in the field coils is  $\frac{33,570 \times 2}{100} = 671.4$  watts. Ans.

(1185) See Arts. **2247**, **2249**, and **2252**.

(1186) From Art. **2285**, the per cent. loss in the core is found by dividing the watts lost in the core by the input, and multiplying by 100. Reducing 64 horsepower to watts gives  $64 \times 746 = 47,744$  watts. Consequently, the loss in the core is  $\frac{800 \times 100}{47,744} = 1.6756\%$ . Ans.

(1187) See Art. **2289**.

(1188) See Art. **2256**.





# DYNAMOS AND MOTORS.

(QUESTIONS 1189-1273.)

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(1189) (*a*) and (*b*) See Art. **2330**.

(1190) See Art. **2338**.

(1191) See Art. **2369**.

(1192) (*a*) Ring. See Art. **2319**. (*b*) Drum. See Art. **2319**.

(1193) See Art. **2293**.

(1194) See Art. **2327**.

(1195) See Art. **2322**.

(1196) An open circuit in the armature winding, probably in the lead to the burned commutator segment. See Art. **2372**.

(1197) (*a*) See Art. **2351**. (*b*) See Art. **2340**.

(1198) (*a*) and (*b*) See Art. **2316**.

(1199) See Art. **2313**.

(1200) See Art. **2326**.

(1201) (*a*) The length of the arm of the brake being 36 inches, or 3 feet, the torque of the motor is  $27 \times 3 = 81$  foot-pounds (Arts. **2346** and **2347**). The revolutions per minute being 900, the H. P. output of the motor is, from formula **334**,

$$\text{H. P.} = \frac{2 \times 3.1416 \, TS}{33,000} = \frac{6.2832 \times 81 \times 900}{33,000} = 13.88 \text{ H. P. Ans.}$$

(b) To find the efficiency, it is first necessary to find the input and reduce the input and the output to the same units (Art. **2347**). In this case the input is  $25 \times 480 = 12,000$  watts. Reducing 13.88 H. P. to watts,  $13.88 \times 746 = 10,354$  watts. Then, by formula **330**, the efficiency  $E = \frac{100 \times 10,354}{12,000} = 86.3\%$ . Ans.

(1202) See Art. **2352**.

(1203) (a) and (b) See Arts. **2381** and **2374**.

(1204) The connections would be about as shown in

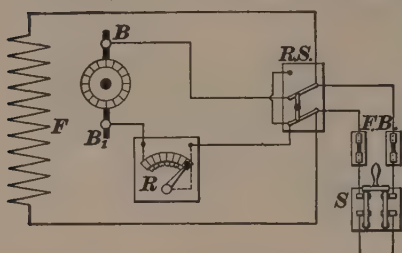


Fig. 98, in which  $F$  is the field circuit,  $B, B_1$  the brushes of the motor,  $R$  the starting resistance,  $R. S.$  the reversing switch,  $F. B.$  the fuse boxes, and  $S$  the main switch.

FIG. 98.

(1205) By varying the applied E. M. F. or the strength of the field. Art. **2341**.

(1206) See Art. **2329**.

(1207) Because the self-induction of the coil having the lesser E. M. F. prevents the flow of current. Art. **2306**.

(1208) Circuit No. 4 (Fig. 925, Art. **2390**) would first be short-circuited by plugging in a cable from terminal -3 to terminal -4. The cable from terminal -3 to terminal +4 may now be removed from terminal +4 and connected to terminal +1, and a cable plugged in from terminal -1 to terminal -B. Then, by pulling out the cable from terminal -3 to terminal -4, circuit No. 1 is connected in series with circuit No. 3, on dynamo  $B$ , as required. The cable from terminal -4 to terminal -B should be removed to make circuit No. 4 "dead."

(1209) (a) See Art. 2378. (b) See Arts. 2367 and 2368.

(1210) (a) See Art. 2295. (b) See Art. 2297.

(1211) (a) 29 amperes flowing out. (b) See Art. 2325.

(1212) See Art. 2353.

(1213) The input to the motor being  $33 \times 230 = 7,590$  watts, and the efficiency being 85%, the output, by formula 333, is  $\frac{7,590 \times 85}{100} = 6,451.5$  watts. This is equal to

$\frac{6,451.5}{746} = 8.65$  H. P. The arm of the brake being 2 feet

long and the pressure on the scale platform being 20 lb., the torque of the motor must be 40 foot-pounds =  $T$ . Knowing the H. P. and the torque, the speed may be found from

formula 335,  $S = \frac{33,000 \text{ H. P.}}{2 \times 3.1416 T}$ . Substituting the above

values for H. P. and  $T$ ,  $S = \frac{33,000 \times 8.65}{2 \times 3.1416 \times 40} = \frac{285,450}{251.328} = 1,136$  revolutions per minute. Ans.

(1214) The frequency is equal to the number of revolutions per second multiplied by the number of pairs of poles (Art. 2318). In this case,  $\frac{1,080}{60} \times \frac{14}{2} = 126$  cycles per second. Ans.

(1215) (a) and (b) See Art. 2393.

(1216) See Art. 2342.

(1217) See Art. 2354.

(1218) See Art. 2376.

(1219) (a) See Art. 2323. (b) See Art. 2322.

(1220) See Arts. 2320 and 2321.

(1221) See Art. 2360.

(1222) See Arts. **2389** and **2407**.

(1223) See Art. **2309** and Fig. 897.

(1224) See Art. **2334**.

(1225) See Art. **2399**.

(1226) See Art. **2356**.

(1227) See Art. **2304**.

(1228) See Art. **2402**.

(1229) See Art. **2365**.

(1230) See Art. **2338**.

(1231) See Art. **2381**.

(1232) See Art. **2384**.

(1233) See Art. **2349**.

(1234) See Art. **2403**.

(1235) See Art. **2315**.

(1236) See Art. **2331**.

(1237) See Art. **2406**.

(1238) When in the position of least action, a coil is momentarily disconnected from the external circuit, then is thrown in parallel with the coil ahead of it, then in series with the other two coils which are then in parallel, then in parallel with the coil behind it, and then disconnected from the circuit again. See Art. **2312**, also Fig. 898.

(1239) (a) See Art. **2352**. (b) See Arts. **2356** and **2359**.

(1240) (a) Of the 5 amperes input, by Ohm's law,  $\frac{125}{62.5} = 2$  amperes go to the field, the loss being, therefore,  $2 \times 125 = 250$  watts. The rest, or  $3 \times 125 = 375$  watts, make up the friction and core losses of the machine (Art. **2349**).

When taking an input of 77 amperes at 125 volts, or 9,625 watts, there would still be required 250 watts for the field, and 375 watts for the core losses and friction. Of the 77 amperes, 75 flow through the armature, and as this has a resistance of .04 ohm, the armature  $C^2 r$  would be  $75^2 \times .04 = 225$  watts. The total losses would then be  $250 + 375 + 225 = 850$  watts, and the output would, therefore, be  $9,625 - 850 = 8,775$  watts, or  $\frac{8,775}{746} = 11.76$  H. P. Ans.

(b) The output being 8,775 watts, and the input 9,625, the efficiency is, by formula **330**,  $\frac{100 \times 8,775}{9,625} = 91.17$  per cent. Ans.

(1241) See Art. **2379**.

(1242) (a) and (b) See Art. **2317**.

(1243) See Art. **2302**.

(1244) See Art. **2338**.

(1245) (a) and (b) See Art. **2396**, and Figs. 928 and 929.

(1246) From Art. **2358**, the speed of the field would be  $\frac{72}{5} = 14.4$  revolutions per second, or  $14.4 \times 60 = 864$  revolutions per minute. With 2.5% slip, the speed of the armature would be  $864 - (864 \times .025) = 842.4$  revolutions per minute. Ans.

(1247) See Art. **2367**.

(1248) (a) See Art. **2336**. (b) and (c) See Art. **2337**.

(1249) When the whole of the coil is directly under one pole piece. See Art. **2386**.

(1250) See Art. **2357**.

(1251) See Art. **2318**.

(1252) See Art. **2405**.

(1253) See Art. **2343**.

(1254) See Art. **2369**.

(1255) (*a*) and (*b*) See Art. **2340**. (*c*) See Arts. **2339** and **2340**.

(1256) See Arts. **2313** and **2314**.

(1257) See Art. **2371**.

(1258) See Art. **2355**.

(1259) See Art. **2336**.

(1260) See Art. **2331**.

(1261) See Art. **2356**.

(1262) There is no definite answer for this problem, as a great number of different arrangements is possible. See Art. **2404**. By comparing it with Fig. 931, Art. **2402**, it will be seen if the connections are correctly made and all the necessary instruments in place; the exact arrangement is a matter of taste and judgment.

(1263) See Art. **2347**.

(1264) See Art. **2319**.

(1265) The frequency being 132, and there being 11 pairs of poles, the motor will run at  $\frac{132}{11} = 12$  revolutions per second, or  $60 \times 12 = 720$  revolutions per minute. See Art. **2352**.

(1266) (*a*) and (*b*) See Arts. **2356** and **2357**.

(1267) See Art. **2298**.

(1268) See Art. **2341**.

(1269) See Art. **2372**.

(1270) See Art. **2298**.

(1271) The diameter of the driving pulley may be found from the formula  $d n \div N$ . In this example, the diameter of the driven pulley is 13 inches, its number of revolutions 700, and the number of revolutions of the driving pulley is 182. Then,  $\frac{13 \times 700}{182} = 50$  inches, the diameter of the driving pulley. Adding 2% for belt slip (Art. 2361) gives  $50 + (50 \times .02) = 51$  inches. Ans.

(1272) (a) The strength of the direct current would be the same as the *effective* strength of the alternating current, which is .7 of its maximum strength. See Art. 2326. Then,  $.7 \times 12 = 8.4$  amperes. Ans.

(b) See Art. 2326.

(1273) See Art. 2341.





# ELECTRIC LIGHTING.

(QUESTIONS 1274-1338.)

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(1274) See Art. **2459**.

(1275) See Art. **2472**.

(1276) See Art. **2509**.

(1277) About 10 amperes.

(1278) See Art. **2412**.

(1279) By formula **349**, the resistance per foot of the conductor  $R_f = \frac{12}{15 \times 610} = .00131$  ohm. By Table 66, this corresponds nearly to No. 11 B. & S. wire. Ans.

(1280) By formula **354**,

$$d^2 = \frac{10.8 \times 1,200}{16} = 810 \text{ circ. mils.} \quad \text{Ans.}$$

(1281) (a) The arc lamps should be connected in groups of two in series, and each group connected in parallel across the 110-volt mains. Ans.

(b) Two arcs require  $2 \times 45 = 90$  volts, leaving  $110 - 90 = 20$  volts to be taken up by resistance. Since the current is 9.5 amperes through the lamps and resistance, and the drop around the resistance is 20 volts,  $R = \frac{20}{9.5} = 2.1$  ohms.

Hence, the auxiliary resistance must be 2.1 ohms, and its carrying capacity 9.5 amperes. Ans.

(1282) About  $3,500^\circ \text{C}$ .

(1283) See Art. **2463**.

(1284) See Art. **2457**.

(1285) (a) Applying Ohm's law,

$$C = \frac{E}{R} = \frac{110}{220} = .5 \text{ ampere. Ans.}$$

(b) Volts  $\times$  amperes = watts =  $110 \times .5 = 55$  watts; or,  
 $\frac{\text{current}^2 \times \text{resistance} = \text{watts} = .5^2 \times 220 = 55 \text{ watts. Ans.}}$

(c) 55 watts for 16 candles, or  $\frac{55}{16} = 3.44$  watts per candle.  
 Ans.

(1286) See Art. 2464.

(1287) (a) See Art. 2417.

(b) See Art. 2417.

(1288) By formula 355, the drop on the line =  
 $\frac{100 \times 125}{90} - 125 = 13.9$  volts, and this added to the voltage  
 at lamps gives the voltage at the generator; that is, 138.9  
 volts. Ans.

(1289) (a) See Art. 2449.

(b) See Art. 2449.

(1290) (a) See Art. 2451.

(b) See Art. 2451.

(1291) See Art. 2410.

(1292) See Art. 2489.

(1293) From Art. 2503, the value of

Three 100 c.p. lamps = 18 of 16 c.p.;

Eight 50 c.p. lamps = 24 of 16 c.p.;

Twelve 32 c.p. lamps = 24 of 16 c.p.

Total..... 66 lamps of 16 c.p. Ans

(1294) See Art. 2507.

(1295) See Art. 2464.

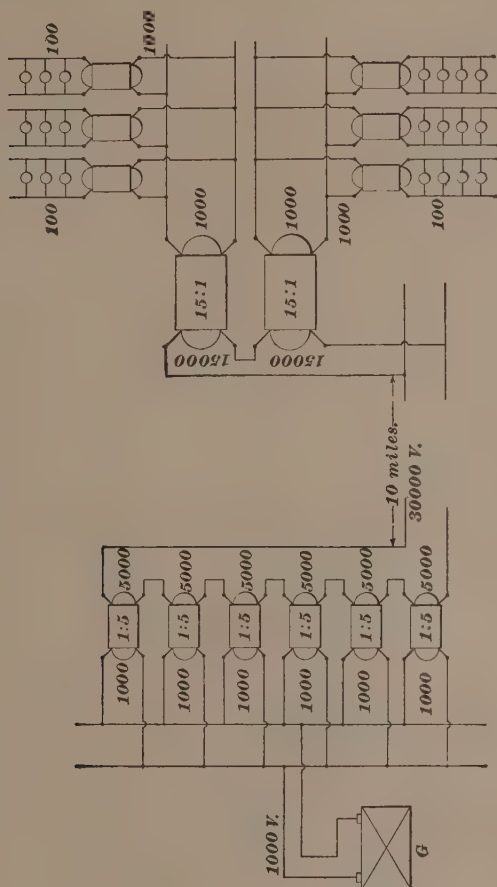
(1296) See Art. 2471. Ans. 220 volts.

(1297) Both are wired on the multiple-arc system.

(1298) See Art. 2470.

(1299) See Art. 2412.

(1300) See Art. 2478, and Fig. 99, below.



(1301) See Art. 2474.

(1302) See Art. 2416.

(1303) By formula 339,

$$R_h = \frac{E}{C} = \frac{100}{.64} = 156.25 \text{ ohms. Ans.}$$

(1304) By formula 353,

$$R = \frac{10.8 \times 760}{95,000} = .0795 \text{ ohm. Ans.}$$

(1305) (a) See Art. 2412.

(b) See Art. 2412.

(1306) (a) Six dynamos.

(b) See Fig. 100.

(1307) See Art. 2475.

(1308) (a) See Art. 2413.

(b) See Art. 2413.

(1309) The actual drop of potential, with 5 per cent. loss, is, by formula 355,

$$E = \frac{100 \times 110}{95} - 110 = 5.79 \text{ volts.}$$

By formula 351, the cross-sectional area of the wire

$$A = \frac{10.8 \times 350 \times 600}{5.79} = 391,710 \text{ circ. mils.}$$

Current per lamp  $\frac{1}{2}$  ampere; 350 lamps require  $350 \times \frac{1}{2} = 175$  amperes.

Referring to Table 70, we find that a cross-section of 391,710 circ. mils has more than the safe carrying capacity of 175 amperes, and, hence, adopt this conductor and require no revision. Ans.

(1310) By formula 337, the illumination

$$I = \frac{3 \times 3 \times 20}{6 \times 6} = 5 \text{ candle power. Ans.}$$

(1311) 10 per cent.

(1312) See Art. 2416.

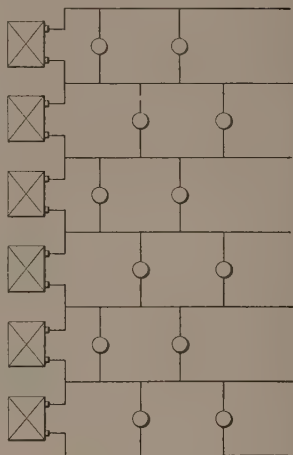


FIG. 100.

(1313) The actual drop of potential is, by formula 355,

$$E = \frac{100 \times 110}{94} - 110 = 7.02 \text{ volts.}$$

By formula 349, the resistance per foot of the conductor

$$R_f = \frac{7.02}{150 \times 600} = .000078 \text{ ohm} = .078 \text{ ohm per 1,000 feet.}$$

Referring to Table 66, this is found to correspond very nearly to No. 00 B. & S. wire, which size could, therefore, be used. Ans.

(1314) See Art. 2472.

(1315) See Art. 2453. The relatively immense cost of the conductors as compared to that required for high-tension work in transmitting the same horsepower.

(1316) 45 volts.

(1317) (a) Two lamps in series with a resistance.

(b) One lamp with resistance.

(1318) (a) Upon the materials of which the electrodes are composed.

(b) Bluish white.

(1319) The number of circular mils required are as follows:

First circuit.....  $10 \times 1,000 = 10,000$ .

Second circuit.....  $60 \times 1,000 = 60,000$ .

Third circuit.....  $30 \times 1,000 = 30,000$ .

Fourth circuit.....  $80 \times 1,000 = 80,000$ .

Fifth or main circuit....  $190 \times 1,000 = 190,000$ .

Using formula 348,

Diameter of 10,000 circular mils =  $\sqrt{10,000} = 100$  mils.

Diameter of 60,000 circular mils =  $\sqrt{60,000} = 245$  mils.

Diameter of 30,000 circular mils =  $\sqrt{30,000} = 174$  mils.

Diameter of 80,000 circular mils =  $\sqrt{80,000} = 283$  mils.

Diameter of 190,000 circular mils =  $\sqrt{190,000} = 435$  mils.

According to Table 66,

|                                               |        |
|-----------------------------------------------|--------|
| 100 mils equivalent to No. 10 B. & S. wire.   | } Ans. |
| 245 mils equivalent to No. 2 B. & S. wire.    |        |
| 174 mils equivalent to No. 5 B. & S. wire.    |        |
| 283 mils equivalent to No. 1 B. & S. wire.    |        |
| 435 mils equivalent to No. 0000 B. & S. wire. |        |

(1320) See Art. **2451**. Drop =  $10 \times 3 = 30$  volts  
Ans.

(1321) See Art. **2463**.

(1322) When the lamp from any cause ceases to operate, it is short-circuited by the cut-out, thereby allowing current to pass for the remaining lamps.

(1323) See Art. **2456**.

(1324) See Art. **2475**.

(1325) See Art. **2440**.

(1326) See Art. **2450**.

(1327) See Art. **2454**.

(1328) See Art. **2436**.

(1329) According to Art. **2451**, the resistances are proportional to the drop in the circuit. Therefore, the relative resistances of the two subdivisions are as  $50:25 = 2:1$ . Ans.

(1330) (a) See Art. **2434**.

(b) By rule in Art. **2434**, the mean spherical candle power =  $\frac{421}{2} + \frac{2,070}{4} = 728$  c.p. Ans.

(1331) The average life is 800 hours.

(1332) See Art. **2455**.

(1333) See Art. **2462**.

(1334) (a) Two dynamos.

(b) In series.

(1335) (a) See Art. **2425**.

(b) Vegetable substances carbonized.

(c) The filament.

(1336) By Art. **2429**, the average watts per candle is 3.44.

(1337) The development of heat.

(1338) By formula **351**, the cross-sectional area of the wire

$$A = \frac{10.8 \times 200 \times 700}{9} = 168,000 \text{ circ. mils.}$$

On reference to Table 66, this size will be found to correspond with No. 000 B. & S.

The determination may also be made by formula **349**, when the resistance per foot of the wire is found to be

$$R_f = \frac{9}{200 \times 700} = .0000643 \text{ ohm} = .0643 \text{ ohm per 1,000 feet.}$$

This resistance also corresponds to No. 000 wire.      Ans.





# ELECTRIC RAILWAYS.

(QUESTIONS 1339-1416.)

(1339) The motor is entirely enclosed in a frame forming part of the magnetic circuit, and supporting shaft and armature. See Art. **2542**.

(1340) (a) See Art. **2545**. (b) Those in which the dead resistance is cut out, and the motors are either in series or parallel.

(1341) (a) An overhead insulated wire carrying current, and a return path through the rails; cars propelled by motors geared to the axles, and supplied with current through a wheel contact held against the overhead wire. See Art. **2526**. (b) The first cost is comparatively small, and the insulation can be made higher than in other systems.

(1342) See Art. **2561**.

(1343) By comparison with a table showing the safe current capacity of the wire. Art. **2567**.

(1344) See Art. **2570**.

(1345) Loss due to belt slipping is avoided, and a saving made in the required engine-room area. Art. **2580**.

(1346) Center poles, or side poles with brackets, or side poles with span wires. Art. **2555**.

(1347) (a) The cables must be tested for insulation resistance and for faults. (b) See Art. **2590**.

(1348) See Art. **2600**.

(1349) See Art. **2602**.

(1350) By formula **374**,

$$f' = [70 + (20 \times 4)] \times 7 = 1,050 \text{ pounds. Ans.}$$

(1351) See Art. **2614**.

(1352) Storage-battery cars; electromagnetic devices in connection with closed conduits; open conduits; third rail, and overhead trolley systems.

(1353) Sixteen or eighteen feet, single trucks. Longer cars usually have double trucks.

(1354) Those with salient and those with consequent-salient poles.

(1355) (*a*) Due to eddy currents set up in the revolving disk. (*b*) No; the increased air gap would cut down the lines of force and reduce the action for a given magnetizing current.

(1356) This is one in which a starting resistance is inserted in the armature circuit and cut out as the speed increases. Art. **2550**.

(1357) See Art. **2556**.

(1358) See Art. **2562**.

(1359) (*a*) See Art. **2572**. (*b*) Reduction of track resistance and consequent saving of power.

(1360) They are required to steady the engine during sudden variations of load, which are of frequent occurrence.

(1361) See Art. **2594**.

(1362) The engines may always be run at full load, and a smaller plant will suffice than would otherwise be required.

(1363) The great weight of the battery requires a large proportion of the available energy for transportation; deterioration is also in most cases very rapid. Art. **2515**.

(1364) (*a*) See Art. **2523**. (*b*) See Art. **2524**.

(1365) The wheel base is the distance between points of contact of wheels, measured along the rail.

(1366) See Art. **2535**.

**(1367) (a) Point 1:**

First half of Rheostat  
 to Field, No. 1 Motor;  
 to Armature, No. 1 Motor;  
 to second half of Rheostat;  
 to Field, No. 2 Motor;  
 to Armature, No. 2 Motor.

Point 2: First half of Rheostat cut out.

Point 3: Second half of Rheostat cut out.

Point 4:

Field, No. 1 Motor;  
 to Armature, No. 1 Motor;  
 to First half of Rheostat.

In parallel with the above:

Second half of Rheostat  
 to Field, No. 2 Motor;  
 to Armature, No. 2 Motor.

Point 5 cuts out one-half, point 6 the whole of Rheostat.

**(b) Point 1:**

Whole Rheostat  
 to Armature, No. 1 Motor;  
 to Field, No. 1 Motor;  
 to Armature, No. 2 Motor;  
 to Field, No. 2 Motor.

Point 2: One-half of Rheostat cut out.

Point 3: Entire Rheostat cut out.

Point 4: Rheostat cut out and Fields  
 shunted.

Point 5: Same as Point 2.

Point 6: Second Motor cut out.

Point 7: Same as Point 6.

Point 8: One-half of Rheostat

to Armature, Motor No. 1;

to Field, Motor No. 1.

Also, Armature, Motor No. 2;

to Field, Motor No. 2;

in parallel with Armature and Field of  
 No. 1.

Point 9: Rheostat cut-out.

Point 10: Rheostat cut out and Fields shunted.

(1368) Trolley wire not less than No. 0 B. & S. hard-drawn copper; span wire No. 5 B. & S. galvanized steel wire.

(1369) The difference of potential between trolley wire and track shall have a certain minimum and a certain average value; also, the conductor must not heat beyond a safe limit.

(1370) From formula **366**, the drop in potential  $e = \frac{5.4 CD}{d^2}$  for a temperature of  $75^\circ$  F. The current in this case is 120 amperes, and by reference to the table of carrying capacity it will be seen that No. 00 wire will rise in temperature about  $13^\circ$  C., or, say  $23^\circ$  F. Then (see Art. **2568**), the resistance of one mil-foot  $= 10.79 \times [1 + (.002155 \times 23)] = 11.32$  ohms. For a distributed load, one-half of this amount is taken, and  $e = \frac{5.66 \times 120 \times 10,560}{133,079} = 54$  volts. Ans.

(1371) The engine should be of lower nominal horsepower than the dynamo, so that at light load the efficiency will not be too low.

(1372) A reflecting galvanometer (Thomson) may be used when there are no disturbing currents in neighboring conductors; when this is the case, only the ballistic galvanometer can be used.

(1373) The battery would be charged when the external load was heavy, because the generator E. M. F. would then be the highest, and would discharge when the external load was light.

(1374) See Art. **2617**.

(1375) By changing the battery connections by means of a controller.

(1376) (a) and (b) See Art. **2531**.

(1377) See Art. **2536**.

(1378) Between  $3\frac{1}{2}$  and 5 to 1.

(1379) See Art. **2551**.

(1380) (a) See Art. **2560**. (b) 6-in. offset.

(1381) For a uniformly distributed load the cross-section of conductor need be only one-half that required when all the load is concentrated at the end of the line.

(1382) See Art. **2575**.

(1383) (a) By incorrect use of the brakes, which allows the wheels to skid; sometimes flats are due to soft spots on the wheel tread. (b) See Art. **2586**.

(1384) See Art. **2590**.

(1385) See Art. **2616**.

(1386) By formula **373**, the horsepower  $H = \frac{hw + Df}{33,000 E}$ . The speed of the car is 9 miles per hour, therefore, the distance covered in 1 minute  $= D = \frac{9 \times 5,280}{60} = 792$  feet, corresponding, on a 7 per cent. grade, to a vertical distance  $h = 792 \times .07 = 55.44$  feet. The weight of car  $w = 9 \times 2,000 = 18,000$  pounds. The force required for propulsion is, by rule **372**,

$$f = 30 \times 9 = 270 \text{ pounds,}$$

$$\text{and } H = \frac{(55.44 \times 18,000) + (792 \times 270)}{33,000 \times .7} = 52.46 \text{ horsepower.}$$

Ans.

(1387) See Art. **2517**.

(1388) By an extension of the yokes under the rails, and the use of a heavy cross-section of metal in their construction.

(1389) In order to prevent oscillation of the car body, which strains the car unnecessarily and also tends to cause slipping of the driving wheels.

(1390) See Art. **2537**.

(1391) Between the canopy switch and controller. See Fig. 1006.

(1392) (a) See Art. **2557**. (b) No. 8 B. & S. galvanized steel wire.

(1393) (a) See Art. **2571**. (b) To avoid the shock to the car on entering curves and to save wear on the track.

(1394) See Art. **2587**.

(1395) (a) The core of the cable is insulated, and a charge given from a battery; the amount of leakage in a certain time is a measure of the insulation resistance. (b) See Art. **2596**.

(1396) The answer is obtained from **371**.

$$D = C' \frac{R_1}{R_1 + R + w}.$$

In this case  $C' = 14,500$ ,  $R_1 = 760$ ,  $R = 950$ , and  $w = 7.3$ . Then, the distance to the fault

$$D = 14,500 \times \frac{760}{760 + 950 + 7.3} = 6,417 \text{ feet. Ans.}$$

(1397) See Art. **2613**.

(1398) The horizontal effort required is greater as the radius of the curve decreases and as the length of wheel base increases.

(1399) (a) and (b) See Arts. **2557** and **2558**.

(1400) (a) From Table 71, the wire to use under these conditions is .6 inch in diameter, when only one is used; if three are used, each wire carries 116.6 amperes and will be say No. 2 wire. By formula **364**, modified for a temperature rise of  $30^\circ$ , the drop will be, in the first case,

$$e = \frac{12.05 \times 350 \times 1,200}{360,000} = 14.06 \text{ volts. Ans.}$$

In the second case,

$$e = \frac{12.05 \times 350 \times 1,200}{3 \times 66,373} = 25.42 \text{ volts. Ans.}$$

(b) If the three wires are to equal the single one in area, they will each be  $\frac{360,000}{3} = 120,000$  circ. mils. The nearest size of wire is No. 00 = 133,079 circ. mils., and the temperature rise will be  $12^\circ \text{ C.}$ , or  $21.6^\circ \text{ F.}$  for 116.6 amperes. Then, the drop

$$e = \frac{11.29 \times 350 \times 1,200}{3 \times 133,079} = 11.9 \text{ volts. Ans.}$$

(1401) See Art. 2585.

(1402) We first find the sum of the resistances through which the deflection for galvanometer constant is obtained.

Resistance of battery  $B = 460$  ohms,

Resistance of galvanometer

and shunt

$$\frac{Gs}{G+s} = 797 \text{ ohms,}$$

Resistance of box

$$r = 1,030,000 \text{ ohms.}$$

$$1,031,257 \text{ ohms.}$$

$$\text{Therefore, } R = \frac{1,031,257}{1,000,000} = 1.031257 \text{ megohms.}$$

$$\text{The multiplying power of the shunt} = \frac{G+s}{s} = \frac{5,980+920}{920}$$

$$= 7.5. \text{ The galvanometer constant} = R d, \frac{G+s}{s} = 2,382.$$

The cable deflection is 203, and the earth current, being against it, is added, making 206. The insulation resistance is, then, by formula 368,

$$I = \frac{2,382}{206} = 11.56 \text{ megohms. Ans.}$$

If the resistance of the battery and galvanometer be disregarded, and  $R$  be taken as  $= r = 1.03$  megohms, the

galvanometer constant will be  $Rd_1 \frac{G+s}{s} = 1.03 \times 308 \times 7.5 = 2,379.3$  and the insulation resistance  $= \frac{2,379.3}{206} = 11.55$  megohms. Ans.

(1403) See Art. 2604.

(1404) See Art. 2605.

(1405) 9 H. P. per car.

(1406) The motors are used as generators, and a small current is taken from them which is used to energize an electromagnetic brake on the car axle, operating directly on the wheels.

(1407) Feeders are intended to carry current from the power house to centers of distribution, and are tapped at no intermediate point.

(1408) The first point to determine is the drop in potential through the known resistance. In the first division, the length of track from the feeder to the end of the line is 2,400 feet. The resistance is 0.03 ohm per mile, and for 2,400 feet will be  $\frac{2,400}{5,280} \times .03 = .0136$  ohm. The total length of road is 24,600 feet, and there being 50 cars, there will be 1 car for each 492 feet. In 2,400 feet there may be  $\frac{2,400}{492} = 5$  cars, and the current will be  $5 \times 16 = 80$  amperes, distributed load. The drop in potential will be

$$e = \frac{80 \times .0136}{2} = 0.54 \text{ volt.} \quad \text{Track I.}$$

For the second division, the length is 2,700 feet, and the resistance is  $\frac{2,700}{5,280} \times .03 = .0153$  ohm. On this length of road there may be  $\frac{2,700}{492} = 6$  cars, and the current will be 96 amperes, distributed load. The drop in potential

$$e = \frac{96 \times .0153}{2} = 0.73 \text{ volt.} \quad \text{Track II.}$$



For the third division, the length is 3,900 feet and the resistance =  $\frac{3,900}{5,280} \times .03 = .022$  ohm. Here, there may be  $\frac{3,900}{492} = 8$  cars, and the current = 128 amperes. The drop

$$e = \frac{128 \times .022}{2} = 1.41 \text{ volts.} \quad \textit{Track III.}$$

For the fourth division, the length is 3,300 feet, and the resistance =  $\frac{3,300}{5,280} \times .03 = .019$  ohm. On this length of road there may be  $\frac{3,300}{492} = 7$  cars, and the current = 112 amperes. The drop

$$e = \frac{112 \times .019}{2} = 1.06 \text{ volts.} \quad \textit{Track IV.}$$

The sections of trolley wire are each 600 feet; then, from sub-feeder to end is 300 feet. In this length there can be but one car, and it may be at any point. The size of wire is No. 0 B. & S.; then the drop of potential

$$e = \frac{5.4 \times 16 \times 300}{105,592} = 0.24 \text{ volt.} \quad \textit{Trolley I, II, III, IV.}$$

*Division I.* The main carries in each half a current of 80 amperes, distributed load. Allowing a temperature rise of  $10^{\circ}$  C., the size of wire will be No. 1; in length it is at each end 300 feet short of the trolley wire, being, therefore, for one-half, 2,100 feet. The area of wire is 83,694 circ. mils, and the drop, by derivation from formula **366**,

$$e = \frac{5.6 \times 80 \times 2,100}{83,694} = 11.2 \text{ volts.} \quad \textit{Ans.} \quad \textit{Main I.}$$

The feeders, both outgoing and return, are alike for any division; the current is double that considered for one-half of the main, and the available drop of potential is  $75 - (.54 + .24 + 11.2) = 63.02$ , or 31.5 volts each. Then, by formula **363**,

$$d^2 = \frac{10.79 \times 160 \times 5,000}{31.5} = 274,031 \text{ circ. mils.}$$

The rise of temperature will be about  $8^{\circ}$  C., and

$$d^2 = \frac{11.12 \times 160 \times 5,000}{31.5} = 282,413 \text{ circ. mils.} \quad \text{Ans.} \quad \text{Feeders I.}$$

*Division II.* The main carries in each half a current of 96 amperes, distributed load, and the length is 2,400 feet. With a temperature rise of  $10^{\circ}$  C., the size wire will be No. 0 = 105,592 circ. mils. The drop in potential

$$e = \frac{5.6 \times 96 \times 2,400}{105,592} = 12.2 \text{ volts.} \quad \text{Ans.} \quad \text{Main II.}$$

This leaves for the feeders a drop of potential of  $75 - (.73 + .24 + 12.2) = 61.83$ , or 30.9 volts each. Then, the area of feeder

$$d^2 = \frac{10.79 \times 192 \times 4,500}{30.9} = 301,701 \text{ circ. mils.}$$

The rise of temperature will be about  $12^{\circ}$  C. Corrected for this,

$$d^2 = \frac{11.29 \times 192 \times 4,500}{30.9} = 315,681 \text{ circ. mils.} \quad \text{Ans.} \quad \text{Feeders II.}$$

*Division III.* The current in each half of the main is 128 amperes, distributed load, and length is 3,600 feet. With a temperature rise of  $10^{\circ}$  C., the size wire will be No. 000, having an area of 167,805 circ. mils. Then, the drop

$$e = \frac{5.6 \times 128 \times 3,600}{167,805} = 15.3 \text{ volts.} \quad \text{Ans.} \quad \text{Main III.}$$

This leaves for the feeders  $75 - (1.41 + .24 + 15.3) = 58.05$  volts, or a drop of 29 volts in each; then,

$$d^2 = \frac{10.79 \times 256 \times 3,800}{29} = 361,948 \text{ circ. mils.}$$

This will involve a temperature rise of about  $18^{\circ}$  C., and corrected for this,

$$d^2 = \frac{11.54 \times 256 \times 3,800}{29} = 387,107 \text{ circ. mils.} \quad \text{Ans.} \quad \text{Feeders III.}$$

*Division IV.* The main carries a distributed load of 112 amperes in each half, and the length is 3,000 feet. For

a temperature rise of  $10^{\circ}$  C., the wire to use is No. 00, in area 133,079 circ. mils. The drop in potential

$$e = \frac{5.6 \times 112 \times 3,000}{133,079} = 14.1 \text{ volts.} \quad \text{Ans.} \quad \text{Main IV.}$$

There is available for the feeders  $75 - (1.06 + .24 + 14.1) = 59.6$  volts for the two, or 29.8 volts each. Then,

$$d^2 = \frac{10.79 \times 224 \times 4,000}{29.8} = 324,424 \text{ circ. mils.}$$

This introduces a rise of about  $15^{\circ}$  C. in temperature, and the area becomes, by correction,

$$d^2 = \frac{11.42 \times 224 \times 4,000}{29.8} = 343,366 \text{ circ. mils.} \quad \text{Ans.} \quad \text{Feeders IV.}$$

(1409) (a) and (b) See Art. **2588**.

(1410) See Arts. **2597** and **2598**.

(1411) (a) The ratio of adhesive force to weight on drivers  $a = \frac{1}{7}$ ; one-half the weight of car is on drivers.

Then, by formula **377**, the maximum grade will be

$$G_r = \frac{\left(\frac{2,000}{2} \times \frac{1}{7}\right) - 30}{20} = 5.64 \text{ per cent.} \quad \text{Ans.}$$

(b) By formula **376**,

$$G_s = \frac{\left(\frac{2,000}{1} \times \frac{1}{7}\right) - 70}{20} = 10.78 \text{ per cent.} \quad \text{Ans.}$$

(1412) See Art. **2559**.

(1413) (a) and (b) See Art. **2577**.

(1414) Formula **370** is applicable here.

$$\text{The insulation resistance } I = \frac{26.06 \times 4}{1.89 \times \log \frac{283}{86}}$$

$$\frac{283}{86} = 3.29. \quad \text{From Fig. 1054, } \log 3.29 = .52, \text{ nearly.}$$

Substituting, we have

$$I = \frac{104.24}{1.89 \times .52} = 105.8 \text{ megohms. Ans.}$$

**(1415)** See Art. **2575**.

**(1416)** The average speed of the cars is 5 miles in one-half hour, or 10 miles an hour, and the distance traveled in one minute is  $\frac{10 \times 5,280}{60} = 880$  feet. The force required to propel the car on the level is 30 pounds per ton, and the weight being 8 tons,  $\frac{8 \times 30 \times 880}{33,000} = 6.4$  horsepower will be required for one car. There are four on the level, and for these the power will be  $6.4 \times 4 = 25.6$  horsepower. For starting on the level we require a force of 70 pounds per ton, and the power required may be determined by the proportion  $30 : 70 = 6.4 : x$ ; whence,  $x = 14.9$  H. P., and for 2 cars, 29.8 H. P. The force necessary for starting on a 3 per cent. grade is, by formula **374**,

$$f' = 70 + (20 \times 3) \times 1 = 130 \text{ pounds per ton.}$$

Then, the power required may be determined by the proportion  $30 : 130 = 6.4 : x$ ; whence,  $x = 27.7$  H. P. The power required in ascending a 5 per cent. grade is found from formula **373**, where, disregarding for the present the question of efficiency,

$$H = \frac{hw + Df}{33,000} = \frac{(44 \times 16,000) + (880 \times 240)}{33,000} = 27.7 \text{ H. P.}$$

The car descending the grade, and that at rest, require no power, and the total horsepower to be delivered at the wheels will be :

|                                         |                   |
|-----------------------------------------|-------------------|
| 4 cars on the level.....                | 25.6 H. P.        |
| 2 cars starting on the level.....       | 29.8 H. P.        |
| 1 car starting on a 3 per cent. grade.. | 27.7 H. P.        |
| 1 car ascending a 5 per cent. grade...  | 27.7 H. P.        |
|                                         | <hr/> 110.8 H. P. |

The efficiency of transmission being 60 per cent., the total horsepower required is  $\frac{110.8}{.60} = 184.6$  H. P. total. Ans.

# DESCRIPTIVE ASTRONOMY.

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- (1) (*a*) and (*b*) See Art. **57**.  
(*c*) See Arts. **59, 68, and 83**.
- (2) (*a*) See Art. **62**.  
(*b*) See Art. **65**.  
(*c*) See Art. **63**.
- (3) (*a*) See Art. **75**.  
(*b*) and (*c*) See Arts. **78, 79, and 80**.
- (4) See Arts. **109 to 117**.
- (5) (*a*) See Art. **119**.  
(*b*) See Arts. **119 and 120**.
- (6) (*a*) See Art. **143**.  
(*b*) See Art. **142**.  
(*c*) See Arts. **142 and 143**.
- (7) (*a*) and (*b*) See Art. **138**.
- (8) See Art. **137**.
- (9) The sun, the planets, and their satellites.
- (10) (*a*) See Art. **148**.  
(*b*) See Arts. **114 to 117**.  
(*c*) See Art. **149**.
- (11) See Art. **150**.
- (12) (*a*) and (*b*) See Art. **151**.

(13) See Art. 152.

(14) (*a*) and (*b*) See Art. 153.

(15) See Art. 153.

(16) (*a*) and (*b*) See Art. 157.

(17) (*a*) and (*b*) See Art. 157.

(18) See Art. 159.

(19) See Art. 159.

(20) (*a*) See Art. 160.

(*b*) See Art. 164.

(*c*) See Art. 179.

(*d*) See Art. 188.

(21) Mercury, about  $7^{\circ}$ ; Venus, about  $3^{\circ} 28'$ ; the Earth,  $23^{\circ} 27'$ ; Mars,  $1^{\circ} 31'$ ; Jupiter,  $1^{\circ} 19'$ ; Saturn, about  $2\frac{1}{2}^{\circ}$ ; Uranus,  $0^{\circ} 46'$ ; Neptune,  $1^{\circ} 47'$ .

(22) See Art. 163.

(23) See Art. 164.

(24) (*a*) See Art. 170.

(*b*) See Art. 177.

(*c*) See Art. 181.

(*d*) See Art. 188.

(25) See Art. 178.

(26) See Art. 180.

(27) See Art. 187.

(28) See Art. 240.

(29) Sirius,  $0.39''$ ; Capella,  $0.11''$ ; Aldebaran,  $0.24''$ ; and Polaris,  $0.089''$ .

(30) See Art. **243**.

(31) See Art. **189**.

(32) See Art. **193**.

(33) See Art. **195**.

(34) See Arts. **202**, **203**, and **204**.

(35) See Art. **207**.

(36) The greatest number of eclipses in a year is **7**.

(37) (*a*) and (*b*) See Art. **208**.

(38) See Art. **208**.

(39) See Arts. **35** and **36**.

(40) (*a*) The difference of latitude of two places is the portion of the meridian included between their parallels.

(*b*) The difference of longitude of two places is the portion of the equator included between the meridians passing through the places.

(41) See Arts. **35** and **36**.

(42) (*a*) See Art. **33**.

(*b*) From the meridian passing through the Observatory at Greenwich, England.

(43) Latitude = zenith distance  $\pm$  declination.

(44) (*a*) See Art. **64**.

(*b*) See Art. **211**.

(45) Follow rule **II**, Art. **127**.

(46) Follow rule **I**, Art. **127**.

(47) Follow rules, Art. 212. Thus,

Sun's decl. Aug. 3d = N  $17^{\circ} 26' 50.9''$

Cor. for 3.7 h. =  $- 2' 25.7''$

Cor. decl. =  $N 17^{\circ} 24' 25.2''$  Ans.

Long. turned into time,  $55^{\circ} 28' = 3$  h. 41 m. 52 s. = 3.7 h

Diff. for 1 hour  $39.39''$

$3.7$

$27573$

$11817$

$60 \overline{) 145.743}$

Cor. =  $2' 25.7''$

(48) Sun's decl. Feb. 19th = S  $11^{\circ} 9' 18.8''$

Cor. for 6.7 h. =  $- 5' 59.0''$

Cor. decl. =  $S 11^{\circ} 3' 19.8''$  Ans.

Long. turned into time,  $100^{\circ} 30' = 6$  h. 42 m. = 6.7 h.

Diff. for 1 hour  $53.59''$

$6.7$

$37513$

$32154$

$60 \overline{) 359.053}$

Cor. =  $5' 59''$

(49) Since the longitude of Cape Horn is west and that of Cape of Good Hope is east, the difference of longitude between them is evidently equal to the sum of their longitudes, or  $67^{\circ} 16' + 18^{\circ} 29' = 85^{\circ} 45'$ , which, turned into time, gives 5 h. 43 m. Ans.

(50) Sun's decl. Nov. 16th = S  $18^{\circ} 49' 38.8''$

Cor. for 5 h. =  $3 6.2$

Cor. decl. =  $S 18^{\circ} 52' 45''$  Ans.

Long. turned into time,  $75^{\circ} 45' = 5$  h. 0 m. 3 s. = 5 h



$$\begin{array}{r}
 \text{Diff. for 1 hour} \quad 37.24'' \\
 \quad \quad \quad 5 \\
 \hline
 60 \overline{) 186.20} \\
 \text{Cor.} = \quad 3' \quad 6.2''
 \end{array}$$

(51) Follow the rule of Art. 214.

$$\begin{array}{ll}
 \text{Decl.} = \text{N } 23^{\circ} 26' 56.4'' & \text{Diff. for 1 hour } 1.12'' \\
 \text{Cor. for 4 h.} = \quad \quad \quad - 4.5 & \text{Long. in time } 4 \text{ h.} \\
 \text{Cor. decl.} = \text{N } 23^{\circ} 26' 51.9'' & \text{Cor.} = 4.48
 \end{array}$$

$$\begin{array}{r}
 \text{True merid. alt.} = \quad 40^{\circ} 17' 21'' \\
 \quad \quad \quad 90^{\circ} \quad 0' \quad 0'' \\
 \hline
 \end{array}$$

$$\text{Zenith dist.} = \text{N } 49^{\circ} 42' 39''$$

$$\text{Declination} = \text{N } 23^{\circ} 26' 51.9''$$

$$\text{Latitude} = \text{N } 73^{\circ} 9' 30.9'' \quad \text{Ans.}$$

$$\begin{array}{ll}
 (52) \quad \text{Decl.} = \text{N } 2^{\circ} 32' 12.3'' \\
 \text{Cor. for 11.2 h.} = \quad \quad \quad + 10' 49.4'' \\
 \text{Cor. decl.} = \text{N } 2^{\circ} 43' 1.7''
 \end{array}$$

$$\begin{array}{r}
 \text{Diff. for 1 hour} \quad 57.98 \\
 \text{Long. in time} \quad 11.2 \text{ h.}
 \end{array}$$

$$11596$$

$$5798$$

$$5798$$

$$60 \overline{) 649.376}$$

$$\text{Cor.} = \quad 10' 49.4''$$

$$\begin{array}{r}
 \text{True merid. alt.} = \quad 88^{\circ} 37' 1'' \\
 \quad \quad \quad 90^{\circ} \quad 0' \quad 0'' \\
 \hline
 \end{array}$$

$$\text{Zenith dist.} = \text{S } 1^{\circ} 22' 59''$$

$$\text{Declination} = \text{N } 2^{\circ} 43' 1.7''$$

$$\text{Latitude} = \text{N } 1^{\circ} 20' 2.7'' \quad \text{Ans.}$$

$$\begin{array}{ll}
 (53) \quad \text{Decl.} = \text{N } 5^{\circ} 25' 49.9'' \\
 \text{Cor. for 1.4 h.} = \quad \quad \quad 1' 20.2'' \\
 \text{Cor. decl.} = \text{N } 5^{\circ} 24' 29.7''
 \end{array}$$

|                                   |                        |             |
|-----------------------------------|------------------------|-------------|
| Diff. for 1 hour                  | 5 7.3 1                |             |
| Long. in time                     | 1.4 h.                 |             |
|                                   | <u>2 2 9 2 4</u>       |             |
|                                   | 5 7 3 1                |             |
|                                   | <u>60 ) 8 0.2 3 4</u>  |             |
| Cor. =                            | 1' 20.2"               |             |
| Obs. alt. sun's lower limb =      | 60° 22'                |             |
| Index-error =                     | + 2' 48"               |             |
|                                   | <u>60° 24' 48"</u>     |             |
| Dip of the horizon =              | - 4' 29"               | (Table II)  |
| App. alt. lower limb =            | <u>60° 20' 19"</u>     |             |
| Semidiameter =                    | + 16' 2"               |             |
| App. alt. sun's center =          | <u>60° 36' 21"</u>     |             |
| Refraction =                      | - 33"                  | (Table I)   |
|                                   | <u>60° 35' 48"</u>     |             |
| Parallax =                        | + 4"                   | (Table III) |
| <b>True alt.</b> =                | <u>60° 35' 52"</u>     |             |
|                                   | <u>90° 0' 0"</u>       |             |
| Zenith dist. =                    | N 29° 24' 8"           |             |
| Declination =                     | N 5° 24' 29.7"         |             |
| Latitude =                        | <u>N 34° 48' 37.7"</u> | Ans.        |
| (54) Obs. alt. of <b>Sirius</b> = | 36° 28' 30"            |             |
| Index-error =                     | - 45"                  |             |
|                                   | <u>36° 27' 45"</u>     |             |
| Dip of the horizon =              | - 4' 9"                |             |
| App. alt. of the * =              | <u>36° 23' 36"</u>     |             |
| Refraction =                      | - 1' 17"               |             |
| <b>True alt.</b> =                | <u>36° 22' 19"</u>     |             |
|                                   | <u>90° 0' 0"</u>       |             |
| Zenith dist. =                    | N 53° 37' 41"          |             |
| Declination =                     | S 16° 34' 38"          |             |
| Latitude =                        | <u>N 37° 3' 3"</u>     | Ans         |

$$\begin{array}{rcl}
 (55) \quad \text{Obs. alt. of Regulus} & = & 50^{\circ} 14' 20'' \\
 \text{Index-error} & = & + 1' 15'' \\
 & & \hline
 & & 50^{\circ} 15' 35'' \\
 \text{Dip of the horizon} & = & - 4' 9'' \\
 & & \hline
 \text{App. alt. of the } * & = & 50^{\circ} 11' 26'' \\
 \text{Refraction} & = & - 48'' \\
 & & \hline
 \text{True alt.} & = & 50^{\circ} 10' 38'' \\
 & & \hline
 & & 90^{\circ} \quad 0' \quad 0'' \\
 \text{Zenith dist.} & = & \text{N } 39^{\circ} 49' 22'' \\
 \text{Declination} & = & \text{N } 12^{\circ} 27' 44'' \\
 & & \hline
 \text{Latitude} & = & \text{N } 52^{\circ} 17' 6'' \quad \text{Ans.}
 \end{array}$$

(56) Consult Art. 265.

$$\begin{array}{rcl}
 \text{Obs. double alt.} & = & 70^{\circ} 40' 19'' \\
 \text{Index-error} & = & - 1' 7'' \\
 & & \hline
 & & 2) 70^{\circ} 39' 12'' \\
 \text{Obs. alt.} & = & 35^{\circ} 19' 36'' \\
 \text{Refraction} & = & - 1' 21'' \\
 & & \hline
 & & 35^{\circ} 18' 15'' \\
 \text{Semidiameter} & = & + 16' 4'' \\
 & & \hline
 & & 35^{\circ} 34' 19'' \\
 \text{Parallax} & = & + 7'' \\
 & & \hline
 \text{True alt.} & = & 35^{\circ} 34' 26'' \quad \text{Ans.}
 \end{array}$$

(57) Consult Art. 221.

$$\begin{array}{rcl}
 \text{H. A.} & = & \text{Local app. time} = 0^h 20^m 1^s \\
 \text{Equation of time} & = & - 3^m 48^s \\
 & & \hline
 \text{Local mean time} & = & 0^h 16^m 13^s \\
 \text{Greenwich mean time} & = & 5^h 0^m 0^s \\
 & & \hline
 \text{Difference} & = & \text{long. in time} = 4^h 43^m 47^s \\
 \text{Longitude} & = & \text{W } 70^{\circ} 56' 45'' \quad \text{Ans.}
 \end{array}$$

(58) The hour-angle (H. A.) is found by the formula of Art. 221, as follows:

$$\cos H. A. = \frac{\sin a - \sin l \cos p}{\cos l \sin p},$$

where  $a = 44^\circ 7'$

$$l = 41^\circ 54'$$

$$p = 90^\circ - 19^\circ 53' = 70^\circ 7'$$

Find in the table of Natural Functions the corresponding values and substitute in the formula.

$$\begin{aligned} \text{Thus, } \cos H. A. &= \frac{.69612 - .66783 \times .34011}{.74431 \times .94039} \\ &= \frac{.46899}{.69994} = .6701; \end{aligned}$$

whence,  $H. A. = \text{local apparent time} = 47^\circ 56'$ ,

or  $\text{turned into time} = 3^h 11^m 44^s$

$$\text{Equation of time} = -3^m 44^s$$

$$\text{Local mean time} = 3^h 8^m$$

$$\text{Greenwich mean time} = 6^h 54^m$$

$$\text{Difference} = \text{long. in time} = 3^h 46^m$$

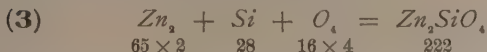
Hence,  $\text{longitude} = W 56^\circ 30'.$  Ans.

# ELEMENTARY CHEMISTRY.

NOTE.—In calculating the percentage, formulas, etc., of the examples, the commonly used atomic weights, which are given in parenthesis under the names of the elements in the Instruction Paper, have been employed.

(1) See Art. 16.

(2) See Arts. 28, 29, and 31.



The molecular weight of zinc orthosilicate being 222, this compound contains 130 parts by weight of zinc, 28 parts by weight of silicon, and 64 parts by weight of oxygen. Applying formula 1, Art. 42, we obtain

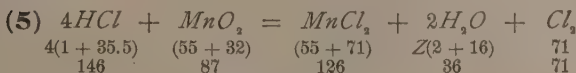
$$Zn = \frac{65 \times 2 \times 100}{222} = 58.56\% \quad \text{Ans.}$$

$$Si = \frac{28 \times 100}{222} = 12.61\% \quad \text{Ans.}$$

$$O = \frac{16 \times 4 \times 100}{222} = 28.83\% \quad \text{Ans.}$$

$$100.00\%$$

(4) See Art. 48.



According to this equation,

- 87 parts of pure  $MnO_2 = 71$  parts of chlorine;
- 100 parts of pure  $MnO_2 = 81.6$  parts of chlorine;
- 30 parts of pure  $MnO_2 = 24.48$  parts of chlorine.

As the sample, weighing 30 grams, produces only 12.04 grams of chlorine, it contains 49.18%  $MnO_2$ . Ans.

(6) See Art. 63.

(7) (a) and (b) See Art. 81.

(8) (a) See Art. 106.

(b) No.

(9) Ferrosoferric oxide, or magnetite,  $Fe_3O_4$ , 72.41% iron.

Ferric oxide, or hematite,  $Fe_2O_3$ , 70% iron.

Hydrated ferric oxide, or limonite,

$2Fe_2O_3, 3H_2O$ , 59.9% iron.

Ferrous carbonate, or siderite,  $FeCO_3$ , 48.27% iron.

Percentage of iron is obtained by employing formula 1, Art. 42.

(10) (a) Vapor density is 99.25.

(b) See Art. 152.

(c)  $HgCl_2$ .

(d) The white of eggs is coagulated by mercury chloride in the stomach, an insoluble compound being thus formed which can not be dissolved by the gastric juice, and therefore can no longer act as a poison.

(11) Oxygen is diatomic, and as ozone, triatomic. Sulphur is diatomic and hexatomic.

(12) See Arts. 1 and 2.

(13) When a dyad and a pentad combine, each has to furnish 10 bonds, 10 being the least common multiple of 5 and 2. To do this, 5 dyads and 2 pentads are required.

(14) The molecular weight of sodium is 106. The atomic weight of  $Na = 23$ ,  $C = 12$ ,  $O = 16$ .

Applying formula 2, the number of atoms of

$$Na \text{ is } \frac{106 \times 43.39}{23 \times 100} = 2,$$

$$C \text{ is } \frac{106 \times 11.32}{12 \times 100} = 1,$$

$$O \text{ is } \frac{106 \times 45.29}{16 \times 100} = 3;$$

hence the formula is  $Na_2CO_3$ .

(15) See Art. 49.

(16) (a) See Art. 57.

(b) Oxygen and ozone, chlorine.

(17) (a) See Art. 64.

(b) I. Atomic weight, 127.

(c) See last part of Art. 64.

(18) (a) and (b) See Art. 82.

(19) See Art. 104.

(20) (a) See Art. 130.

(b) See Art. 131.

(21) 
$$\begin{array}{rcccl} \text{HgCl}_2 & + & \text{Hg} & = & \text{Hg}_2\text{Cl}_2 \\ (200 + 71) & & 200 & & 471 \end{array}$$

Using formula 6, Art. 44, we obtain

$$\frac{271 \times 3}{471} = 1.73 \text{ kilograms HgCl}_2. \quad \text{Ans.}$$

$$\frac{200 \times 3}{471} = 1.27 \text{ kilograms Hg.} \quad \text{Ans.}$$

(22) (a) and (b) See Art. 4.

(23) See Art. 11.

(24) (a) See Art. 18.

(b) See Art. 19.

(25)  $\text{NaCl}$ , sodium chloride.  
 $\text{SrO}$ , strontium oxide.  
 $\text{SnO}$ , stannous oxide.  
 $\text{SnO}_2$ , stannic oxide.

(26) 
$$\begin{array}{rcccl} 2\text{CaO} & + & 2\text{Cl}_2 & = & 2\text{CaCl}_2 & + & \text{O}_2 \\ 2(40 + 16) & & 2(71) & & 2(40 + 71) & & 2(16) \\ 112 & & 142 & & 222 & & 32 \end{array}$$

By using formula 6, Art. 44,

$$W = \frac{112 \times 39}{16 \times 2} = 136.5 \text{ grams of CaO.} \quad \text{Ans.}$$

(27) See Art. 51.

(28) See Art. 56.

(29) See Art. 68.

(30) See Arts. 83 and 84.

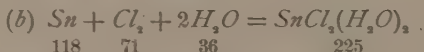
(31) Ethylene dichloride.

(32) 
$$\frac{\text{NiAs}_2}{\underbrace{59 + (75 \times 2)}_{209}} \quad \frac{59 \times 1 \times 100}{209} = 28.23\% \text{ nickel. Ans.}$$

(33) (a) Silver chloride.

(b) Used in photography because it possesses the property of turning black on exposure to light.

(34) (a) See Art. 162.



Using formula 8, Art. 44,

$$\frac{225 \times 250}{118} = 476.7 \text{ kilograms. Ans.}$$

(35) See Art. 6.

(36) See Art. 14.

(37) (a) See Art. 21.

(b) Atoms are classified as monads, dyads, triads, tetrads, hexads, and heptads.

(38) (a) See Art. 32.

(b) See Art. 33.

(39) By using formula 3, Art. 43, we obtain

$$a = \frac{150 \times 78.67}{1 \times 100} = 118, \text{ atomic weight of tin. Ans.}$$

(40) Symbol, O. Density, 16. Atomic weight, 16. Valence, II.

(41) See Art. 56.

(42) See Art. 69.



(43) (a) See Art. 89.

(b)  $\frac{1}{50000}$  of a grain of arsenious acid in 100-grain measures of the solution can be detected.

(44) See Art. 111.

(45) See Art. 134.

(46) (a)  $\text{No}$ ; gold is soluble only in aqua regia.

(b) See Arts. 158 and 159.

(47) See Art. 7.

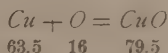
(48) See Art. 22.

(49) See Art. 23.

(50) By using formula 4, Art. 43, we obtain

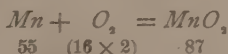
$$m = \frac{65 \times 1 \times 100}{87} = 97, \text{ molecular weight of zinc sulphide.} \quad \text{Ans.}$$

(51) (a)  $\text{CuO}$ .



$$\frac{66 \times 1 \times 100}{79.5} = 20.13\% \text{ O.} \quad \text{Ans.}$$

(b)  $\text{MnO}_2$ .



$$\frac{16 \times 2 \times 100}{87} = 36.78\% \text{ O.} \quad \text{Ans.}$$

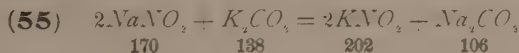
(52) Rock salt, being a compound of sodium and chlorine.

(53) (a) See Art. 70.

(b) Because it crystallizes in two forms belonging to two distinguished systems, it is called a dimorphous element.

(c) See Art. 70.

(54) See Art. 92.



Using formula **8**, Art. **44**,

$$\frac{1,000 \times 202}{170} = 1,188.23 \text{ grams of } KNO_3. \quad \text{Ans.}$$

- (56) (a) Potassium, 24.68%.  
Manganese, 34.82%.  
Oxygen, 40.50%.

Molecular weight of compound, 316.

Using formula **2**, Art. **43**, we obtain

$$\text{Potassium, } \frac{24.68 \times 316}{39 \times 100} = 2.$$

$$\text{Manganese, } \frac{34.82 \times 316}{55 \times 100} = 2.$$

$$\text{Oxygen, } \frac{40.5 \times 316}{16 \times 100} = 8.$$

The formula, therefore, is  $K_2Mn_2O_8$ .

(b) Potassium permanganate.

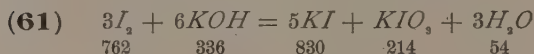
(57) (a) and (b) See Art. **160**.

(c) Being unaltered by single acids, moisture, air, or heat, it is especially useful in the arts and in the laboratory.

(58) See Art. **10**.

(59) (a) and (b) See Art. **24**.

(60) (a) and (b) See Arts. **35** and **36**.



Employing formula **6**, Art. **44**, we obtain

$$(a) \quad \frac{762 \times 210}{166 \times 5} = 192.8 \text{ grams of iodine.} \quad \text{Ans.}$$

$$(b) \quad \frac{336 \times 210}{166 \times 5} = 85.01 \text{ grams of potassium hydrate.} \quad \text{Ans.}$$

(62) See Art. **51**.

(63) See Art. **55**.

(64) See Art. 72.

(65) See Art. 92.

(66)  $3Na_2SO_4 + 4CaCO_3 + 13C = 3Na_2CO_3 + 3CaS + CaO + 14CO$ .

Using formula 8, Art. 44, we obtain

$$\frac{318 \times 721}{426} = 538.2 \text{ kilograms. Ans.}$$

(67) See Art. 138.

(68) See Art. 12.

(69) *Fe, Sn, Na, Al.*

(70)  $2NaOH + H_2SO_4 = 2H_2O + Na_2SO_4$ , sodium sulphate.

(71)  $CH_4 + 2O_2 = CO_2 + 2H_2O$ .

Two volumes of methane and 4 volumes of oxygen yield 2 volumes of carbon dioxide and 4 volumes of water.

(72) No.

(73) See Art. 58.

(74) See Art. 73.

(75) (a) See Art. 96.

(b) See Art. 98.

(c) See Art. 98.

(76) (a) and (b) See Arts. 121 and 122.

(77) See Art. 140.

(78) See Art. 15.

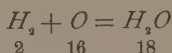
(79) Twelve atoms of titanium, 4 atoms of phosphorus, 6 atoms of sulphur.

(80) See Art. 37.

(81) (a) Seventy-two.

(b) Metals and metalloids.

(c) See Art. 47.

(82)  $H_2O$ .

$$\frac{2 \times 100}{18} = 11.11\% \text{ hydrogen. Ans.}$$

$$\frac{16 \times 100}{18} = 88.88\% \text{ oxygen. Ans.}$$

(83)  $HCl$ , 36.5, 18.25. See Art. 59.

(84) See Art. 62.

(85)  $K_4SiO_4$ .

(86) (a) See Art. 123.

(b) See Art. 124.

(87) (a) See Art. 144—Occurrence of lead.

(b) See Art. 144.

(88) See Art. 25.

(89) See Art. 26.

(90) (a) See Art. 39.

(b) See Art. 39.

(c) See Art. 39.

(91) (a) See Art. 46.

(b)  $\left\{ \begin{array}{l} \text{Metalloids: } Cl, P, S, N, As, H. \\ \text{Metals: } K, Na, Fe. \end{array} \right.$

(92) (a) See Art. 53.

(b) See Art. 54.

(93) See Art. 60.

(94) (a) and (b) See Art. 79.

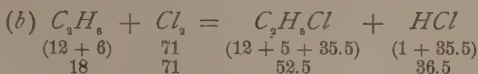
(95) (a) and (b) See Art. 99.

(96) See Art. 126.

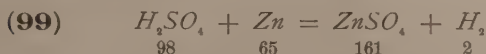
(97) (a)  $CuSO_4$ .

(b) and (c) See Art. 142.

(98) (a) See Art. 41.



Eighteen parts of ethyl hydride + 71 parts of chlorine yield 52.5 ethyl chloride and 36.5 parts of hydrogen chloride.



If 1 liter weighs .0896 gram, 10 liters weigh .896 gram.

Using formula 6, Art. 44,

$$IV = \frac{98 \times .896}{2} = 43.9 \text{ grams of sulphuric acid. Ans.}$$



$$\frac{16 \times 500}{18} = 444.44 \text{ grams of oxygen.}$$

$$\frac{2 \times 500}{18} = 55.56 \text{ grams of hydrogen.}$$

$$\frac{444.44 \times 11.2}{16} = 311.11 \text{ liters of oxygen. Ans.}$$

$$55.555 \text{ gr.} \times 11.2 = 622.27 \text{ liters of hydrogen. Ans.}$$

(101) Molecular weight: 98,  $H_2SO_4$ .

Properties. See Art. 75.

(102) See Art. 80.

(103) (a) See Art. 102.

(b) Use formula 2.

(c) See Art. 102.



## BLOWPIPING.

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- (1) See Art. 2.
- (2) See Arts. 3 and 4.
- (3) See Arts. 6 and 7.
- (4) See Arts. 8 and 9.
- (5) See Art. 10.
- (6)  $Al_2(OH)_3$ ;  $Cr_2(SO_4)_3$ .
- (7) See Art. 15.
- (8) See Arts. 16 to 19.
- (9) See Art. 22.
- (10) See Art. 12.
- (11) See Art. 13.
- (12) See Art. 14.
- (13) See Art. 13.
- (14) See Art. 31.
- (15) See Arts. 33 and 34.
- (16) See Arts. 44 to 46.
- (17) See Art. 48.
- (18) See Arts. 49 to 53.
- (19) See Art. 54.
- (20) See Art. 36.
- (21) See Art. 37.
- (22) See Arts. 41 to 43.
- (23) See Art. 94.

- (24) See Arts. **96** to **98**.
- (25) See Arts. **96** and **98**.
- (26) See Arts. **96** and **98**.
- (27) See Arts. **96** and **98**.
- (28) See Arts. **99** and **100**.
- (29) See Arts. **58** and **59**.
- (30) See Art. **100**.
- (31) See Arts. **105** and **106**.
- (32) See Arts. **101** and **102**.
- (33) See Art. **103**.
- (34) See Art. **104**.
- (35) See Arts. **107** to **111**.
- (36) See Tables **III** and **IV**.
- (37) See Tables **V** and **VI**.
- (38) See Arts. **112** to **114**.
- (39) See Art. **115**.
- (40) See Table **VII**.
- (41) See Art. **96**.
- (42) See Art. **117**.
- (43-50). No Key.



## MINERALOGY.

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- (1) See Art. 1.
- (2) See Art. 2.
- (3) See Arts. 9 and 10.
- (4) See Art. 10.
- (5) See Art. 4.
- (6) See Art. 12.
- (7) See Arts. 5 and 6.
- (8) See Art. 11.
- (9) See Arts. 1 to 17.
- (10) See Arts. 14 to 16.
- (11) See Art. 8.
- (12) See Arts. 18 and 19.
- (13) See Art. 19.
- (14) See Art. 21.
- (15) See Art. 22.
- (16) See Art. 29.
- (17) See Art. 36.
- (18) See Art. 36.
- (19) See Art. 80.
- (20) See Art. 81.
- (21) See Arts. 39 to 45.
- (22) See Art. 38.
- (23) See Arts. 39 to 45.
- (24) See Art. 44.

- (25) See Art. 42.
- (26) See Art. 59.
- (27) See Art. 60.
- (28) See Arts. 65 to 71.
- (29) See Art. 70.
- (30) See Art. 72.
- (31) See Art. 78.
- (32) See Art. 47.
- (33) See Art. 55.
- (34) See Art. 53.
- (35) See Art. 49.
- (36) See Table I.
- (37) See Table I.
- (38) See Art. 66.
- (39) See Art. 85.
- (40) See Arts. 85 to 90.
- (41) See Table II and Arts. 101 and 104.
- (42) See Art. 92.
- (43) See Table I and Art. 94.
- (44) See Table II and Arts. 101 and 102.
- (45) See Art. 98.
- (46) See Art. 98.
- (47) See Art. 98.
- (48) See Art. 98.
- (49) See Art. 98.
- (50) See Table II.
- (51) See Arts. 44 and 49.
- (52) See Art. 64.
- (53) See Arts. 99 to 104.

## GEOLOGY.

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- (1) See Art. 1.
- (2) See Art. 2.
- (3) See Art. 4.
- (4) See Art. 13.
- (5) See Art. 8.
- (6) See Art. 14.
- (7) See Art. 14.
- (8) See Art. 21.
- (9) See Art. 23.
- (10) See Art. 26.
- (11) See Art. 27.
- (12) See Arts. 28 to 30.
- (13) See Arts. 31 and 32.
- (14) See Art. 35.
- (15) See Art. 38.
- (16) See Art. 40.
- (17) See Art. 42.
- (18) See Art. 45.
- (19) See Art. 46.
- (20) See Art. 48.
- (21) See Art. 49.
- (22) See Art. 50.
- (23) See Art. 52.

- (24) See Arts. **53** and **54**.
- (25) See Art. **55**.
- (26) See Art. **56**.
- (27) See Art. **59**.
- (28) See Art. **63**.
- (29) See Art. **66**.
- (30) See Art. **68**.
- (31) See Art. **69**.
- (32) See Art. **70**.
- (33) See Arts. **73** to **80**.
- (34) See Art. **81**.
- (35) See Arts. **82** to **89**.
- (36) See Arts. **79** and **82**.
- (37) See Art. **92**.
- (38) See Art. **94**.
- (39) See Art. **98**.
- (40) See Art. **99**.
- (41) See Arts. **109** to **113**.
- (42) See Art. **116**.
- (43) See Art. **118**.
- (44) See Arts. **121** to **124**.
- (45) See Art. **124**.
- (46) See Art. **127**.
- (47) See Arts. **128** and **129**.
- (48) See Art. **132**.
- (49) See Art. **140**.
- (50) See Art. **141**.
- (51) See Art. **147**.
- (52) See Arts. **148** and **149**.

- (53) See Art. **152.**
- (54) See Art. **156.**
- (55) See Art. **160.**
- (56) See Art. **169.**
- (57) See Art. **171.**
- (58) See Art. **174.**
- (59) See Art. **175.**
- (60) See Art. **154.**
- (61) See Arts. **181** and **182.**
- (62) See Arts. **186** and **187.**
- (63) See Art. **189.**
- (64) See Arts. **190** to **192.**
- (65) See Art. **195.**
- (66) See Arts. **203** to **207.**
- (67) See Arts. **208** and **209.**
- (68) See Arts. **216** to **218.**
- (69) See Art. **227.**
- (70) See Arts. **244** to **249.**
- (71) See Art. **250.**
- (72) See Art. **260.**





